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NEARSHORE GREAT LAKES ICE STATISTICS

S. J. Bolsenga
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K. M. Hinkel

Great Lakes Environmental Research Laboratory
Ann Arbor, Michigan
August 1988

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UNITED STATES
DEPARTMENT OF COMMERCE

C.William Verity
Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

Environmental Research
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NEARSHORE GREAT LAKES ICE STATISTICS[1]

S. J. Bolsenga, G. M. Greene, and K. M. Hinkel

ABSTRACT. Data collected from an ice thickness and stratigraphy network from 1965-66 through 1978-79 permit definition of nearshore ice thickness conditions. The data are summaries for 29 locations in the Great Lakes.

1. INTRODUCTION

The thickness and composition of ice in the nearshore zone of the Great Lakes is of interest to those involved in a variety of activities. For example, shoreline structure design is greatly influenced by the severity of ice conditions in any given area. The location and design of power plant cooling intakes are affected by the ice conditions expected at the site. Recreation is often affected by the amount and type of ice present.

To fill a need for ice thickness information, a network was organized to collect ice thickness and stratigraphy data. Data were collected from the 1965-66 season through the 1978-79 season at many of the stations in the network. The sites selected for observation varied widely in their physical characteristics, such as water depth and exposure to the elements. Each station is described in the following analysis.

Two factors tend to bias the ice information at most of the stations. Since the observer often walked from the shoreline to the station, the locations could nearly always be classified as nearshore. Also, observers were instructed to collect measurements in areas where ridging and other extreme fluctuations in ice thicknesses were not likely to occur. That would tend to cause observations to be collected in sheltered areas, such as bays or coves. Extreme ice thicknesses were never reported, although it is obvious that ridged ice formations are likely to occur in many locations close to these stations. In addition, the stations used for analysis in this report were selected on the basis of data reliability and period of record. Synoptic coverage of a lake basin is most often not achieved, and statistics based on such data are biased. Where such factors are known, they are mentioned.

Each station was to be located at least 50 m from the shore in an area free from obstructions that might cause above-average snow drifting. The observer bored a hole in the ice with an auger and hooked a folding ruler with a foot attachment under the bottom of the ice. The thickness of each ice type, as well as snow and slush layers, was read by sighting through the borehole to the ruler. The observation and reporting procedures, as well as a tabular listing of the data, are given in Sleator (1978).

[1]GLERL Contribution No. 559

This report represents an analysis of a portion of the data selected on the basis of reliability, period of record, and geographic location. Stations selected are shown in Figure 1. Station numbers correspond to the locations listed in the table of contents. Additional analyses are presented in Assel et al.(1984), Bolsenga (1984), Greene (1983), and Hinkel (1983). At some stations, two seasons of additional unpublished data not reported by Sleator (1978) were available.

For purposes of this report, freeze-up has been defined as that time when approximately 5 cm of ice has formed and continues to grow. If a few centimeters of ice formed, subsequently deteriorated, and reformed at a later date, freeze-up was reported at the later date. Breakup is considered to have occurred when the ice is either gone or is in such a deteriorated state as to cause no problem to even small boat traffic. Throughout the report, the first, second, third, or last week of the month is referenced. Days of the month 1 through 7 constitute the first week, 8 through 15 the second, 16 through 23 the third, and 24 through 31 the last. All of the statistics in this report are based on that timeframe. However, all of the graphics have been plotted on a 10-day period basis. The information is presented on a lake-by-lake and station-by-station basis. It is thus necessary to refer only to the specific locations of interest to obtain information about that location.

Figure 1.--Locations of stations. Station numbers correspond to locations listed in the table of contents.

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2. ANALYSIS

2.1 Lakewide Averaged Freeze-up, Maximum Thickness, and Breakup Dates and Amounts

One of the more interesting statistics compiled in this study indicates that the average date of nearshore zone freeze-up for each of the Great Lakes was in the last week in December.

The average date of nearshore zone maximum ice thickness was latest for the Lake Superior stations (March 8-15). Average dates for maximum ice thickness on Lakes Michigan and Huron were between February 24 and 28; average dates for maximum ice thickness on Lake Ontario were between February 16 and 23; and average dates for maximum ice thickness on Lake Erie were between February 1 and 7. It was expected that Lake Erie would show the earliest date of maximum ice thickness because of heat budget factors related to its small water volume.

Maximum ice thicknesses exhibited a rather unusual pattern. Of all the lakes, Lake Huron had the highest average maximum ice thickness (54 cm), even higher than Lake Superior's. That is probably because of the inclusion in the Lake Huron average of data from two stations on the St. Marys River. Average maximum amounts of those two stations were 60 and 67 cm. Lakes Michigan and Superior had average maximum thicknesses of 52 cm, Lake Ontario 42 cm, and Lake Erie 33 cm.

Lake Erie showed the earliest average nearshore zone breakup date (March 8-15); Lakes Huron and Ontario showed average breakup dates 2 weeks later (April 1-7). Lakes Superior and Michigan recorded average breakup dates a full month after Lake Erie (April 8-15).

2.2 Lakewide Averaged Growth and Dissipation Rates

On the basis of limited statistical data, it appears that the nearshore- zone ice growth rate was nearly equal for all the lakes. Lake Ontario had the highest average growth rate (9 mm/day); the other lakes had averages of 8 mm/day. In contrast, ice dissipation rates showed high values for the upper lakes (Lake Huron--17 mm/day, Lake Michigan--16 mm/day, Lake Superior--14 mm/day) and low values for the lower lakes (Lake Ontario--12 mm/day, Lake Erie--11 mm/day). As might be expected, on the upper lakes ice cover lasted longer, averaging 104 days. On the lower lakes the season was about 3 weeks shorter, averaging 82 days.

In comparison with the above data, average ice growth rates on a small pond in New Hampshire varied from 5 mm/day to 9 mm/day (Gow and Govoni, 1983). Average ice dissipation rates varied from 17.5 mm/day to 23 mm/day. It is apparent that the growth rates in the Great Lakes compare favorably with the higher rates in the small body of water, and dissipation rates on the Great Lakes tend to compare favorably with the lower end of the range for the inland lake.

2.3 Lakewide Averaged White Ice Amounts

"White ice" (mode of formation often unknown) thickness was computed as a percentage of total ice thickness for each year at each station, and the values followed fairly predictable patterns. Lake Superior stations averaged the highest percentage of white ice (25 percent). Lake Ontario stations averaged a lower percentage of white ice (21 percent). Lakes Michigan and Huron were equal in terms of average white ice percentages (17 percent). Lake Erie stations averaged the lowest percentage (7 percent). The Lake Ontario value is probably biased because most of the reporting stations are at the eastern end of the lake where heavy snowfalls prevail.

On Post Pond in New Hampshire (Gow and Govoni, 1983), snow ice contributed from 7 percent to 50 percent of total ice thickness, indicating highly variable conditions. An examination of white ice contributions to total ice thickness for individual years at each of the Great Lakes stations indicates an even higher variability than on Post Pond. In some cases, Great Lakes ice was reported to be nearly all white ice.

2.4 Lake Superior

Ten reporting stations are included in the Lake Superior analysis (Fig. 1). The average time of freeze-up for all stations was the last week in December. The average time of freeze-up at individual stations varied widely, from the first week in December at Chequamegon Bay through the last week in January at Grand Portage Bay. Ice thickness reached a maximum (whole-lake average) in the second week in March. Average ice thicknesses for a particular station reached a maximum as early as the third week in February at Mosquito Bay and as late as the third week in March at Gros Cap Light, L'Anse Bay, and Portage Lake. Maximum ice thickness averaged 52 cm for all stations and varied from 35 cm to 68 cm. The station with the highest average maximum amount (68 cm) was Chequamegon Bay. The station with the lowest average maximum amount (35 cm) was, interestingly enough, the northernmost station in this analysis--Grand Portage Bay. Also, very little white ice was reported at that station. Breakup dates for Lake Superior showed little variance. The average breakup date for all stations was in the second week in April. The average breakup date at individual stations varied from the last week in March at Grand Portage Bay to the last week in April at Portage Lake. The sheltered location of that inland lake station (Portage Lake) probably caused breakup there to be late.

Ice growth rates for all stations averaged about 8 mm/day. The lowest average growth rate (6 mm/day) was found at Portage Lake, and the highest (10 mm/day) at the Chequamegon Bay-Ashland, Wis., station. Ice dissipation rates were much higher than growth rates; the whole-lake average rate for Lake Superior was 14 mm/day. The average ice dissipation rate was highest (18 mm/day) at L'Anse Bay and Gros Cap Light. Both of those areas are subjected to high winds because of their exposure. The average ice dissipation rate was lowest (10 mm/day) at Tahquamenon Bay. Average whole-lake ice duration was 107 days, varying from 142 days at Tahquamenon Bay to 68 days at Grand Portage Bay. It is interesting to note that the Grand Portage Bay average maximum thickness and duration figures are very close to the average

maximum thickness (33 cm) and duration (74 days) for all Lake Erie stations. It is possible that Grand Portage Bay ice conditions are influenced by the outflow of the nearby Pigeon River.

White ice as a percentage of total ice averaged 25 percent for all stations. The lowest average of white ice (9 percent) was recorded at Duluth, Minn., and the highest (57 percent) at Portage Lake. Analysis of data for individual stations follows.

2.4.1 Mosquito Bay

The Mosquito Bay station (46°28'N, 84°28'W) is at the head of the St. Marys River near Brush Point on the United States side. It is well sheltered and removed from the often severe weather of Whitefish Bay.

The average freeze-up time at this station was the first week in January; times varied from the first week in December through the third week in January. The average time of maximum ice thickness was the third week in February; times varied from the last week in January through the third week in March. Maximum ice thickness averaged 40 cm, varying from 33 cm to 47 cm. The average time of breakup was the second week in April; times varied from the last week in March through the last week in April.

Ice growth rates at this station averaged 8 mm/day; dissipation rates averaged 9 mm/day. The number of days from freeze-up to maximum ice thickness averaged 52 days (a 30-93 day range), and from maximum ice thickness to breakup, 46 days (a 20-63 day range). Ice cover duration averaged 98 days and varied from 91 days to 106 days.

White ice averaged 33 percent of total ice and varied from 12 percent to 52 percent. Figure 2 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice. Figure 3 shows the wide range of total ice thicknesses and of freeze-up and breakup dates at this station.

2.4.2 Gros Cap Light

The Gros Cap Light station (46°31'N, 84°36'W) is at the eastern end of Whitefish Bay between Point Iroquois on the United States side and Gros Cap on the Canadian side. It is in an area of shoals well away from the shore near the United States-Canadian border, which roughly bisects the area between Point Iroquois and Gros Cap. This station should be representative of much of the open water Whitefish Bay ice.

The average time of freeze-up at this station was the third week of January. The 2-week delay from the average freeze-up date at Mosquito Bay was expected since the Gros Cap Light station is located in an open water area. Freeze-up occurred as early as the last week in December and as late as the first week in February. The average time of maximum ice thickness was the

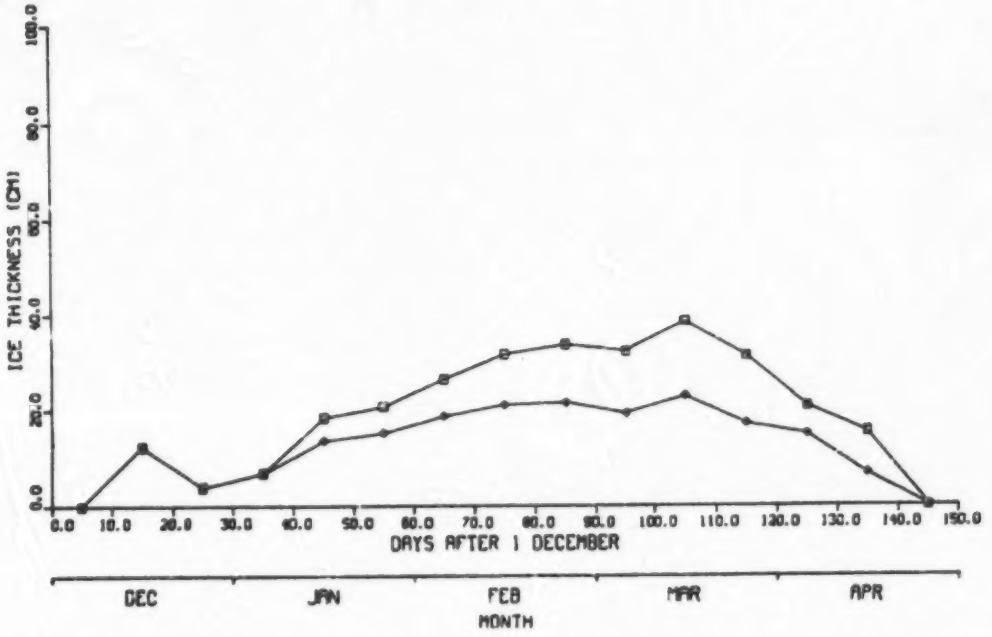

Figure 2.--Average total ice and clear ice thicknesses at Mosquito Bay for 1965-79.

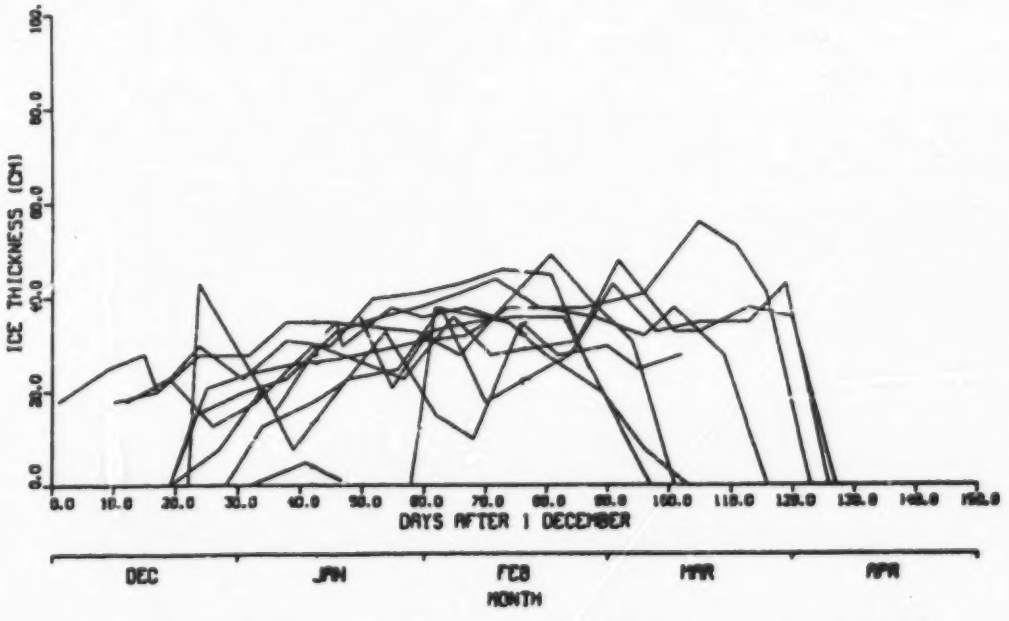

Figure 3.--Total ice thicknesses recorded at Mosquito Bay from 1965-79.

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third week in March; times varied from the third week in February through the first week in April. Maximum ice thickness averaged 50 cm, varying from 23 cm to 69 cm (a range much greater than that at Mosquito Bay). The average time of breakup was the third week in April; times varied from the third week in March through the second week in May.

Ice growth rates at this station averaged 9 mm/day; dissipation rates averaged 18 mm/day. The growth rate was close to that at the Mosquito Bay station, but the dissipation rate was twice that at Mosquito Bay. Presumably this is because the Gros Cap station is so exposed and the wind and wave action are consequently severe. The number of days from freeze-up to maximum ice thickness averaged 56 days (a 33-76 day range), and from maximum ice thickness to breakup, 28 days (a 21-35 day range). Ice cover duration averaged 85 days and varied from 42 days to 111 days.

White ice averaged only 17 percent of total ice and varied from 5 percent to 39 percent. Figure 4 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice. Figure 5 shows the wide range of total ice thicknesses and of freeze-up and breakup dates at this station.

2.4.3 Point Iroquois

The Point Iroquois station (46°30'N, 84°37'W) is on Whitefish Bay approximately three-fourths of the distance from Point Iroquois to Gros Cap Light. It is close to the Gros Cap Light station and thus would be expected to have similar ice conditions. This was indeed found to be the case. Both stations are among the farthest from shore of those discussed in this report.

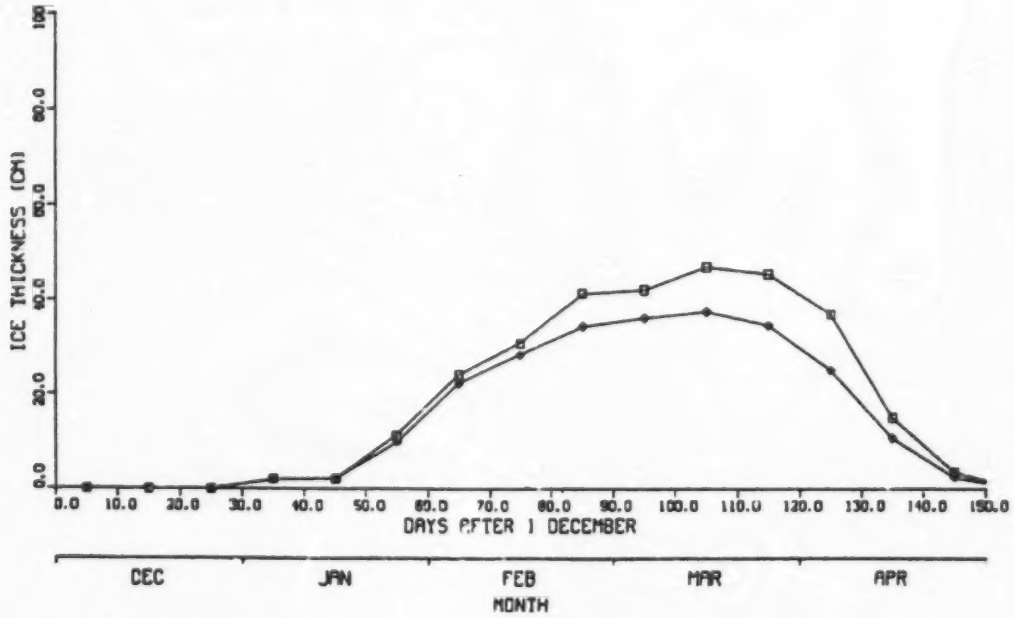

Figure 4.--Average total ice and clear ice thicknesses at Gros Cap for 1965-79.

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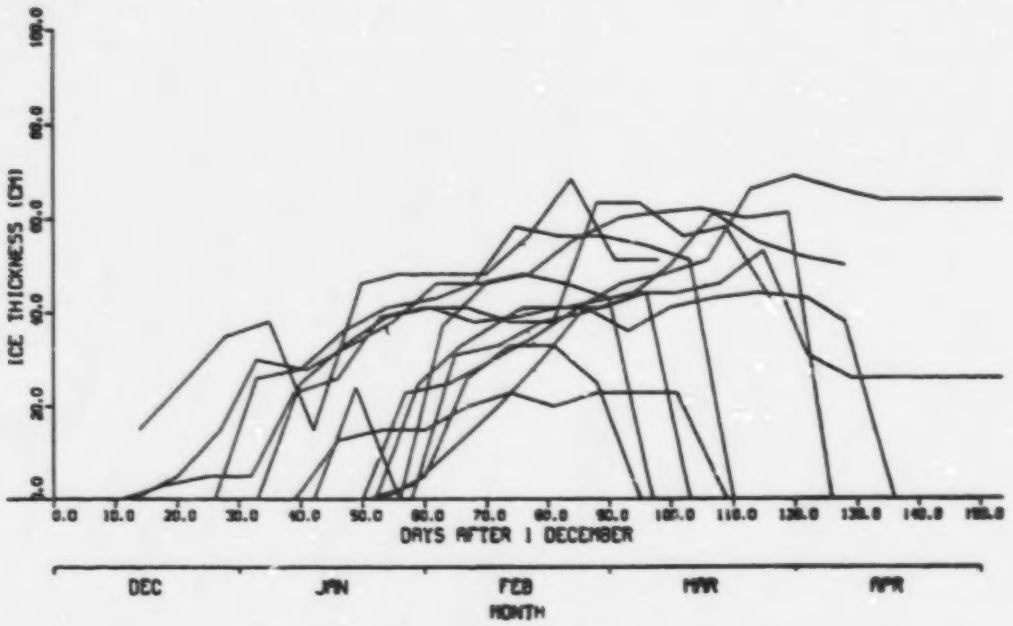

Figure 5.--Total ice thicknesses recorded at Gros Cap from 1965-79 (shown to indicate data variability).

The average time of freeze-up at this station was the second week in January; times varied from the last week in December through the first week in February. The average time of maximum ice thicknesses was the second week in March; times varied from the third week in February through the last week in March. Maximum ice thickness averaged 49 cm, varying from 28 cm to 76 cm. The average time of breakup was the third week in April; times varied from the last week in March through the first week in May.

Ice growth rates at this station averaged 9 mm/day; dissipation rates averaged 14 mm/day. The number of days from freeze-up to maximum ice thickness averaged 54 days (a 31-77 day range), and from maximum ice thickness to breakup, 36 days (a 21-52 day range). Ice cover duration averaged 90 days and varied from 70 days to 105 days.

White ice averaged 26 percent of total ice and varied widely, from 0 percent to 99 percent. Figure 6 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice.

2.4.4 Tahquamenon Bay

The Tahquamenon Bay station (46°32'N, 85°01'W) is east of Whitefish Point just south of Paradise, Mich. It is in a nearshore area of the bay about one-third of the distance between the shoreline and Tahquamenon Island.

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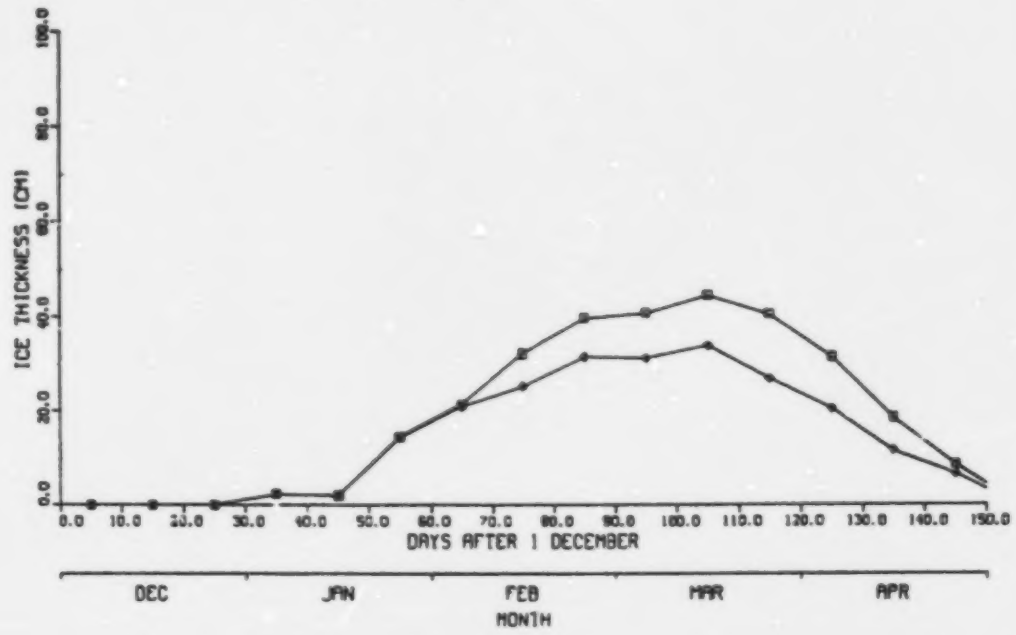

Figure 6.--Average total ice and clear ice thicknesses at Point Iroquois for 1965-79.

The average time of freeze-up at this station was the third week in December. Freeze-up occurred as early as the second week in December and as late as the first week in January. The average time of maximum ice thickness was the second week in March; times varied from the third week in February through the third week in April. Maximum ice thickness averaged 60 cm, varying from 25 cm to 76 cm. The average time of breakup was the third week in April; times varied from the last week in March through the last week in April.

Ice growth rates at this station averaged 7 mm/day; dissipation rates averaged 10 mm/day. The number of days from freeze-up to maximum ice thickness averaged 86 days (a 59-108 day range), and from maximum ice thickness to breakup, 56 days (a 41-90 day range). Ice cover duration averaged 142 days and varied from 106 days to 168 days.

White ice averaged 31 percent of total ice and varied from 9 percent to 42 percent. Figure 7 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice.

2.4.5 South Bay-Munising

The South Bay-Munising station (46°25'N, 86°39'W) is close to the shoreline over about 6.0-8.0 m of water. It is sheltered from the main portion of Lake Superior by South Bay itself and by Grand Island to the north.

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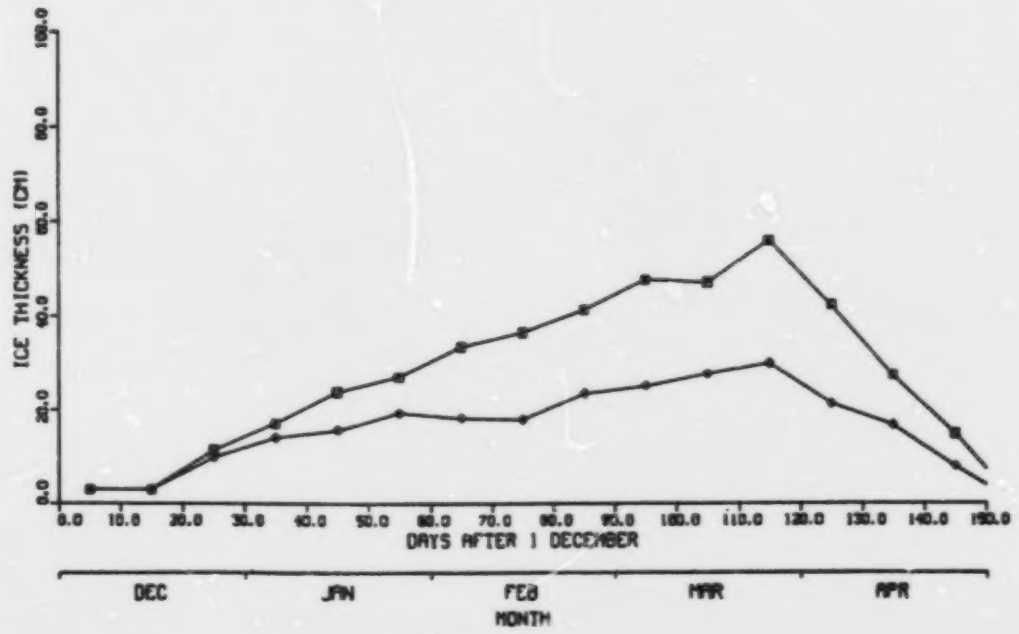

Figure 7.--Average total ice and clear ice thicknesses at Tahquamenon Bay for 1965-79.

The average time of freeze-up at this station was the last week in December; times varied from the first week in December through the third week in January. It is interesting that the average freeze-up date is so close to that for Tahquamenon Bay. The station is considerably removed geographically from that station, but its physical characteristics, such as the degree of exposure, are similar. The average time of maximum ice thickness was the second week in March; times varied from the first week in March through the last week in March. Maximum ice thickness averaged 49 cm, varying from 26 cm to 68 cm. The average time of breakup was the third week in April; times varied from the second week in April through the first week in May.

Ice growth rates at this station averaged 7 mm/day; dissipation rates averaged 13 mm/day. The number of days from freeze-up to maximum ice thickness averaged 72 days (a 53-91 day range), and from maximum ice thickness to breakup, 38 days (a 21-56 day range). Ice cover duration averaged 110 days and varied from 90 days to 140 days.

White ice averaged 18 percent of total ice and varied from 7 percent to 36 percent. Figure 8 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice. Figure 9 shows the wide range of total ice thicknesses and of freeze-up and breakup dates at this station.

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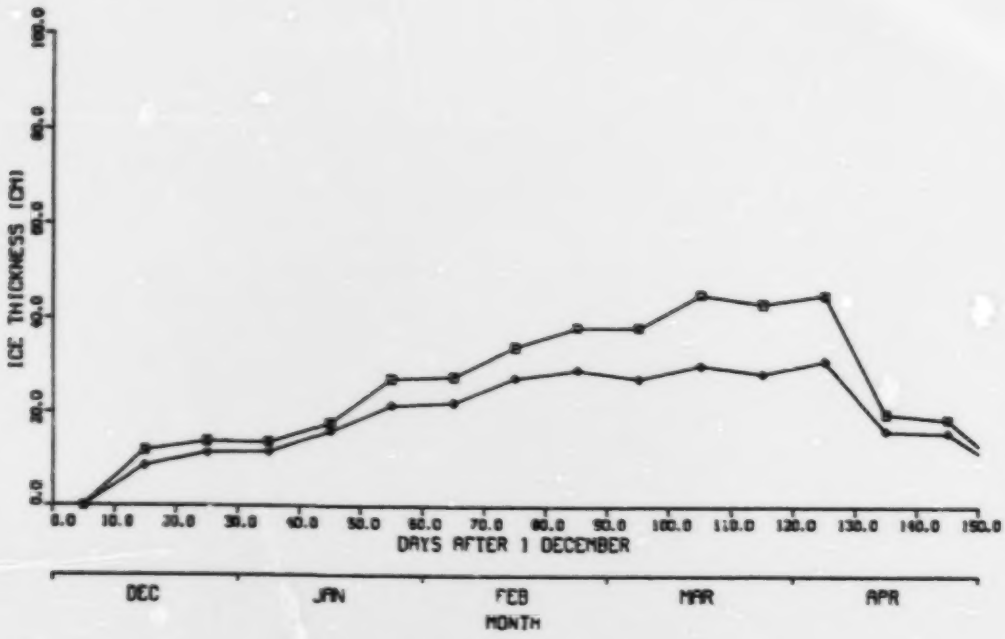

Figure 8.--Average total ice and clear ice thicknesses at South Bay-Munising for 1965-79.

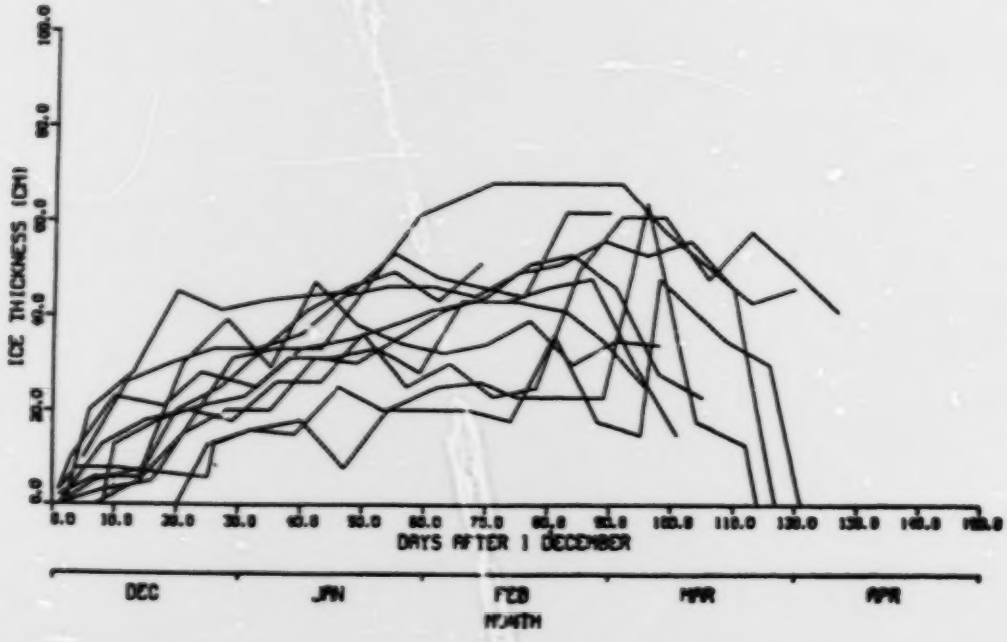

Figure 9.--Total ice thicknesses recorded at South Bay-Munising from 1965-79.

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2.4.6 L'Anse Bay

The L'Anse Bay station (46°46'N, 88°28'W) is offshore of Baraga, Mich., over about 21.0-23.0 m of water. It is minimally sheltered from the harsh effects of the main portion of Lake Superior by a point of land directly to the north.

The average time of freeze-up at this station was the second week in January; times varied from the last week in December through the first week in February. The average time of maximum ice thickness was the third week in March; times varied from the last week in February through the first week in April. Maximum ice thickness averaged 46 cm, varying from 25 cm to 61 cm. The average time of breakup was the second week in April; times varied from the last week in March through the third week in April.

Ice growth rates at this station averaged 7 mm/day; dissipation rates averaged 18 mm/day. The number of days from freeze-up to maximum ice thickness averaged 63 days (a 36-87 day range), and from maximum ice thickness to breakup, 26 days (a 14-49 day range). Ice cover duration averaged 89 days and varied from 61 days to 104 days.

White ice averaged 15 percent of total ice and varied from 4 percent to 32 percent. Figure 10 shows the average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice. Figure 11 shows the wide range of total ice thicknesses and of freeze-up and breakup dates at this station.

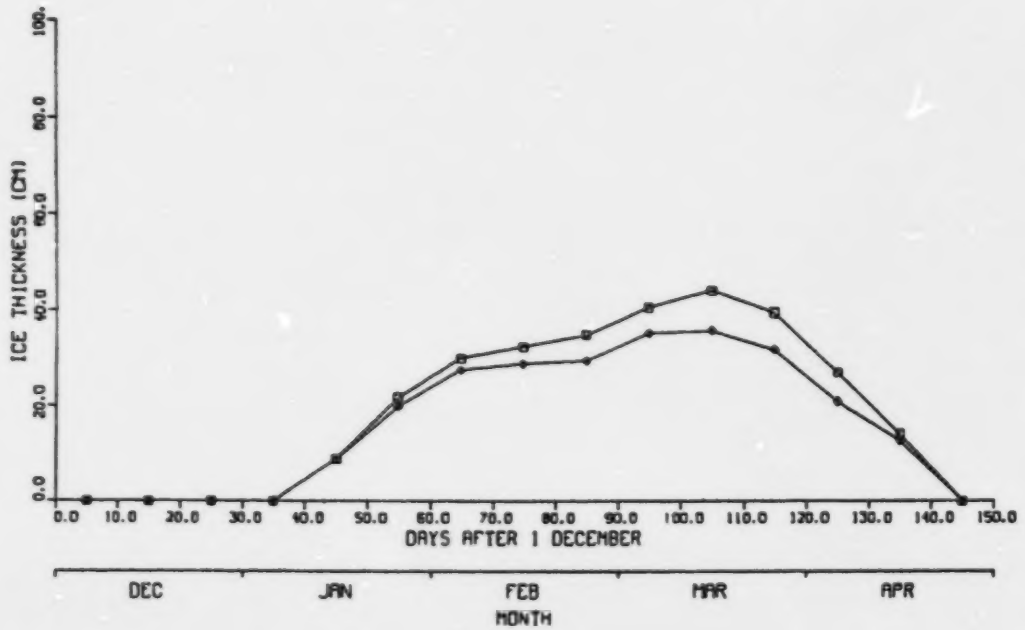

Figure 10.--Average total ice and clear ice thicknesses at L'Anse Bay for 1965-79.

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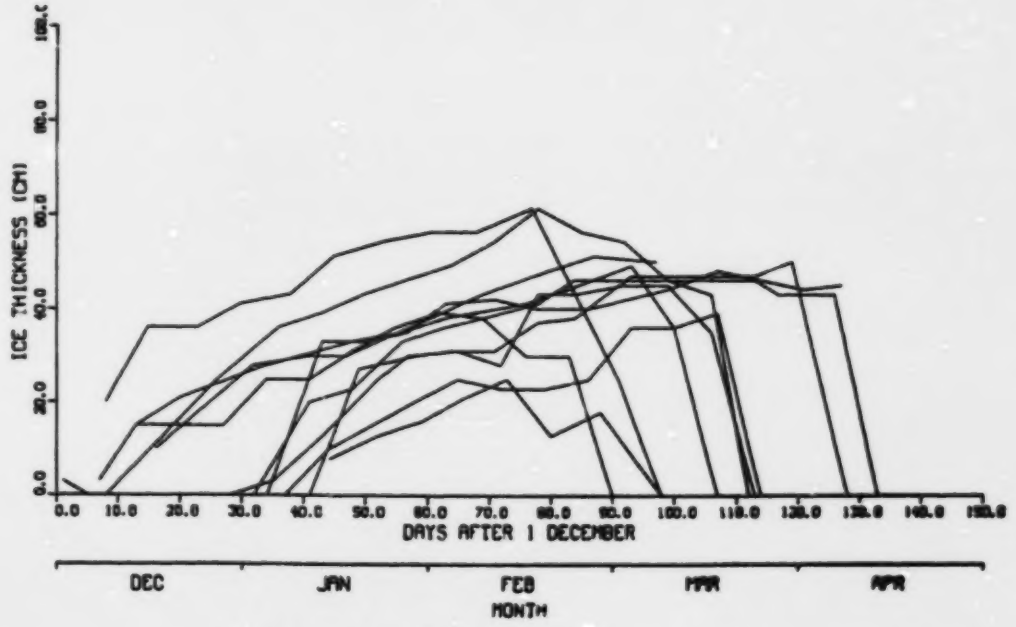

Figure 11.--Total ice thicknesses recorded at L'Anse Bay from 1965-79.

2.4.7 Portage Lake

The Portage Lake station (47°02'N, 88°31'W) is on the western shore of an inland lake over about 12.0 m of water midway between Pilgrim Point to the north and Chassel, Mich., to the south.

This station showed the earliest average freeze-up date of any of the stations described thus far (second week in December), although another Lake Superior station (Chequamegon Bay) described later showed an even earlier date. Freeze-up occurred as early as the first week in December and as late as the second week in January. Ice thickness reached a maximum, on the average, in the third week in March; times varied from the first week in March through the first week in April. Maximum ice thickness averaged 52 cm, varying from 45 cm to 63 cm. The average time of breakup was the last week in April; times varied from the second week in April through the second week in May.

Ice growth and dissipation rates did not vary appreciably from those at the previously described stations (6 mm/day and 13 mm/day, respectively). The number of days from freeze-up to maximum ice thickness averaged 95 days (a 57-115 day range), and from maximum ice thickness to breakup, 39 days (a 32-62 day range). Ice cover duration averaged 134 days and varied from 111 days to 143 days.

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The most unusual aspect of the Portage Lake station was the high percentage of white ice exhibited. White ice averaged 57 percent of total ice and varied from 41 percent to 73 percent. Figure 12 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice.

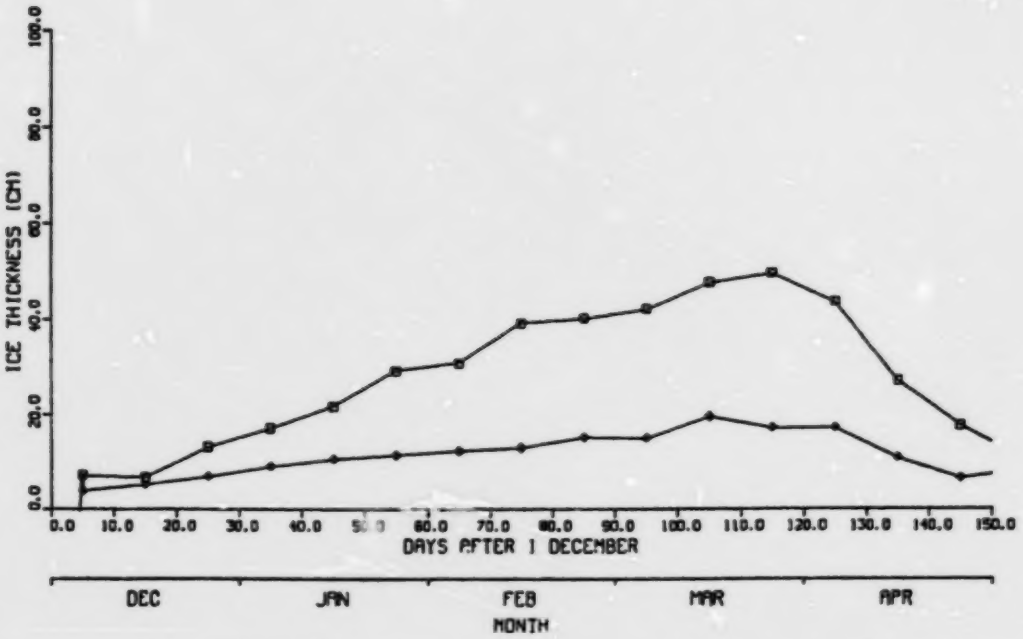

Figure 12.--Average total ice and clear ice thicknesses at Portage Lake for 1965-79.

2.4.8 Chequamegon Bay-Ashland

The Chequamegon Bay station (46°35'N, 90°55'W) is offshore of Ashland, Wisconsin, over a 6.4-m-deep maintained channel area inside a breakwall. It is sheltered from moving ice on Lake Superior.

The average time of freeze-up at this station was the first week in December; times varied from the last week in November through the second week in December. The average time of maximum ice thickness was the first week in March, varying from the last week in January through the second week in April. Maximum ice thickness averaged 68 cm, varying from 46 cm to 99 cm. The average time of breakup was the second week in April; times varied from the last week in March through the first week in May.

Ice growth rates at this station averaged 10 mm/day; dissipation rates averaged 17 mm/day. The number of days from freeze-up to maximum ice thickness averaged 92 days (a 57-121 day range), and from maximum ice thickness to breakup, 39 days (an 8-79 day range). Ice cover duration averaged 131 days and varied from 110 days to 150 days.

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White ice averaged 30 percent of total ice and varied from 0 percent to 86 percent. Figure 13, a plot of the average total and clear ice thicknesses at this station, shows a rather smooth symmetrical shape. The area between the two curves is the average thickness of white ice.

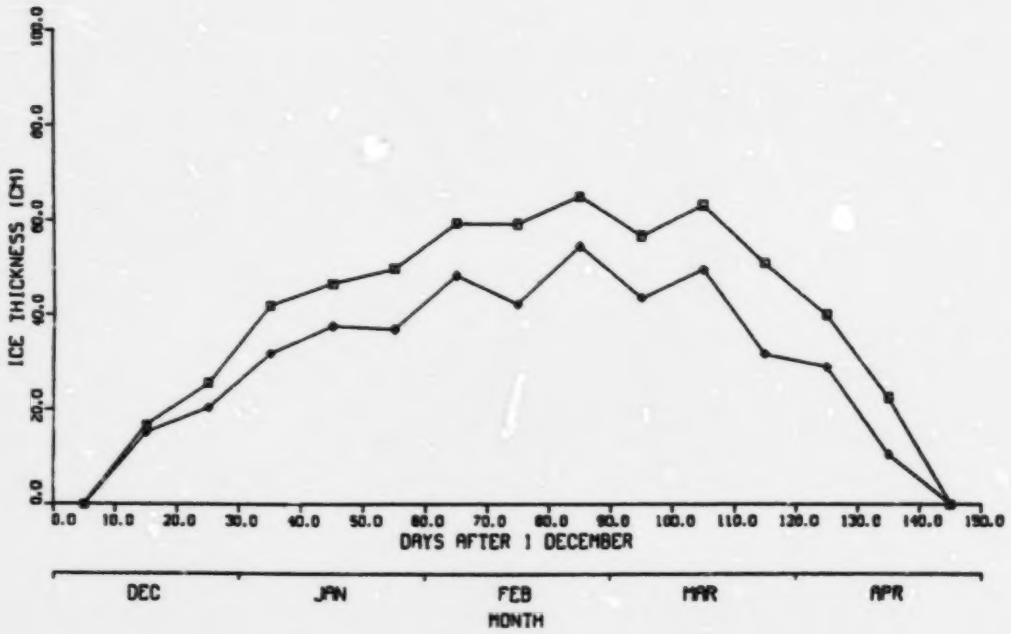

Figure 13.--Average total ice and clear ice thicknesses at Chequamegon Bay-Ashland for 1965-79.

2.4.9 Duluth Harbor

The Duluth Harbor station (46°46'N, 92°06'W) is in an anchorage area of the Duluth Harbor basin over about 8.0 m of water. It is well within the harbor area and thus protected from the main portion of Lake Superior.

The average time of freeze-up at this station was the second week in December; times varied from the last week in November through the third week in December. The average time of maximum ice thickness was the last week in February; times varied from the first week in February through the second week in March. Maximum ice thickness averaged 67 cm, varying from 56 cm to 84 cm. The average time of breakup date was the second week in April; times varied from the last week in March through the last week in April.

Ice growth rates at this station averaged 8 mm/day; dissipation rates averaged 16 mm/day. The number of days from freeze-up to maximum ice thickness averaged 80 days (a 71-86 day range), and from maximum ice thickness to breakup, 44 days (a 28-57 day range). Ice cover duration averaged 124 days and varied from 119 days to 130 days.

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White ice averaged 9 percent of total ice and varied from 1 percent to 20 percent. Figure 14, a plot of average total and clear ice thicknesses at this station, shows a rather smooth pattern and a little white ice. The area between the two curves is the average thickness of white ice.

2.4.10 Grand Portage Bay

The Grand Portage Bay station (47°57'N, 89°39'W) is east of Grand Portage, Minn., near Hat Point. It is over about 3.0 m of water in a small bay open to Lake Superior except for a small island in the middle of the entrance to the bay.

The average time of freeze-up at this station was the last week in January; times varied from the first week in January through the second week in February. The average time of maximum ice thickness was the first week in March; times varied from the last week in February through the last week in March. Maximum ice thickness averaged 35 cm, varying from 23 cm to 53 cm. The average time of breakup was the last week March; times varied from the first week in March through the last week in April.

Ice growth rates at this station averaged 9 mm/day, while dissipation rates averaged 13 mm/day. The number of days from freeze-up to maximum ice thickness averaged 41 days (a 14-62 day range), and from maximum ice thickness to breakup, 27 days (a 6-35 day range). Ice cover duration averaged 68 days and varied from 49 days to 90 days.

Figure 15, a plot of average total and clear ice thicknesses at this station, shows very little white ice. The area between the two curves is the average thickness of white ice.

2.5 Lake Michigan

Four reporting stations are included in the Lake Michigan analysis (Fig. 1). Because three of the stations are located on the western shore of the lake near or in Green Bay, it is likely that all lakewide average statistics are biased toward that location. The average time of freeze-up for all stations was the last week in December. The average time of freeze-up at individual stations varied from the first week in December at Green Bay, Wis., through the first week in January at Menominee, Mich. It is surprising that the latest average freeze-up date would occur at a station so close to the station with the earliest average freeze-up date. Ice thickness reached a maximum (whole-lake average) in the last week in February. Average ice thicknesses for a particular station reached a maximum as early as the second week in February at Muskegon Lake and as late as the second week in March at Menominee. Maximum ice thickness averaged 52 cm for all stations and varied from 33 cm at Muskegon Lake to 62 cm at Escanaba, Mich. The average breakup date for Lake Michigan was in the second week in April. Average breakup dates at individual stations varied from the last week in March at Green Bay through the third week in April at Menominee.

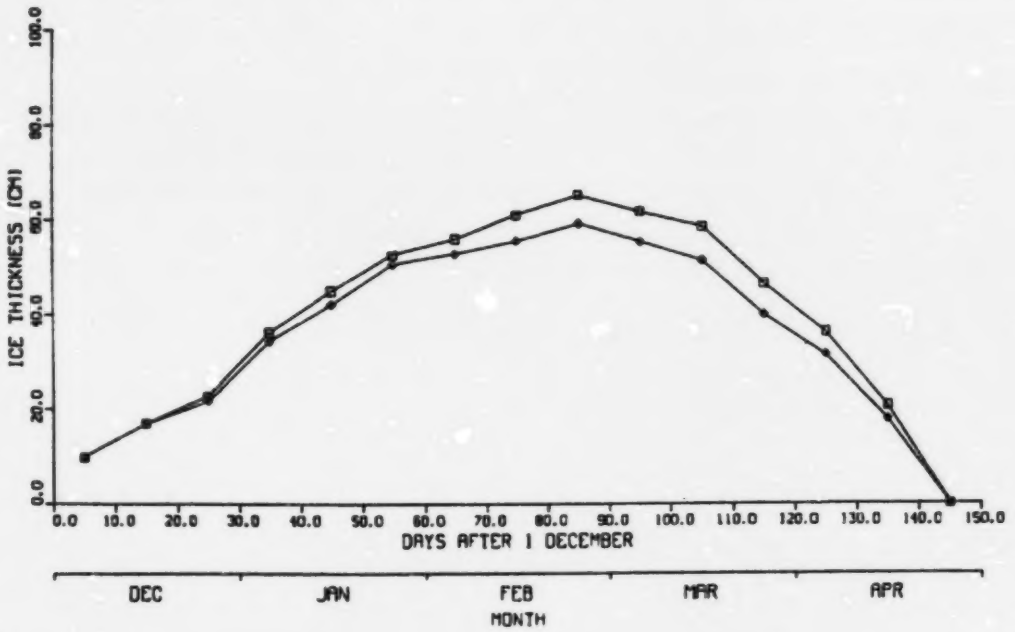

Figure 14.--Average total ice and clear ice thicknesses at Duluth Harbor for 1965-79.

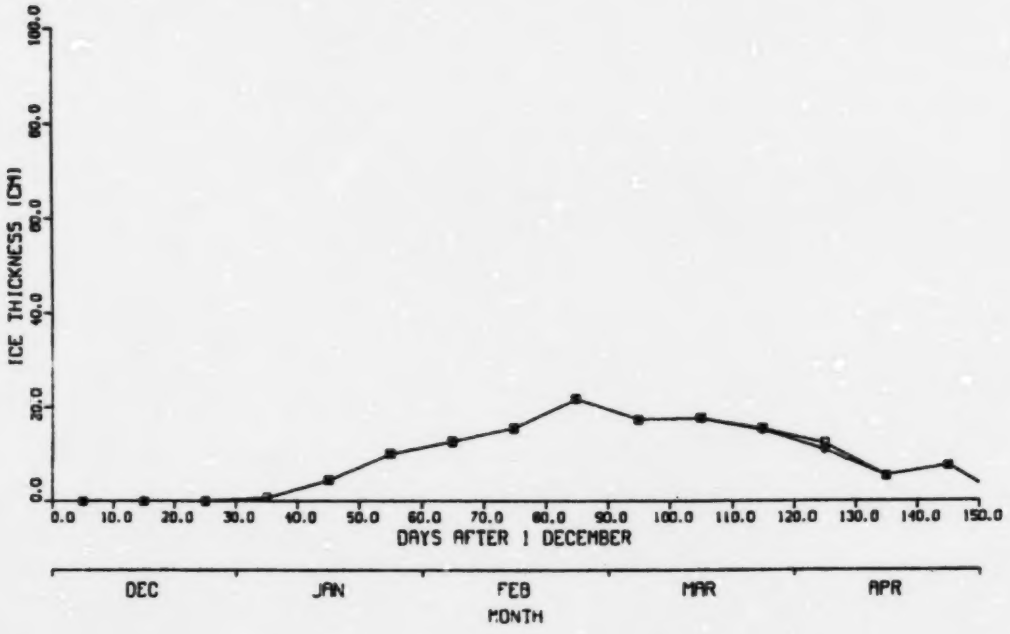

Figure 15.--Average total ice and clear ice thicknesses at Grand Portage Bay for 1965-79.

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The average ice growth rate for all stations was the same as that for Lake Superior (8 mm/day). The highest average growth rate (11 mm/day) was found at Escanaba and the lowest (6 mm/day) at Muskegon. Generally higher temperatures at the lower latitude station (Muskegon) would contribute to that result. The average ice dissipation rate for all stations (16 mm/day) was slightly higher than that at Lake Superior. Average ice dissipation rates for individual stations varied from 7 mm/day at Muskegon Lake to 26 mm/day at Menominee. The low dissipation rate at Muskegon Lake could be attributed to the sheltered location of that station. The average whole-lake ice duration was 100 days as opposed to 107 days for Lake Superior. Average ice durations varied from 90 days at Menominee to 115 days at Green Bay.

White ice as a percentage of total ice averaged 13 percent for all stations. The lowest average of white ice (5 percent) was recorded at Escanaba and Menominee, and the highest averages (18 percent and 23 percent) at Muskegon and Green Bay, respectively. The high percentage of snow ice to total ice at Muskegon is easily explained: Weather systems move from west to east across the lake and pick up moisture that is later precipitated over land. Analysis of data for individual stations follows.

2.5.1 Green Bay

The Green Bay station (44°34'N, 87°55'W) is at the southwestern end of Green Bay near Green Bay, Wis., over a water depth of about 3.0 m. Sable Point lies to the north. The measurement area is on the eastern shoreline, well away from the main body of Lake Michigan; it can possibly be viewed as a large inland lake in terms of ice conditions.

The average time of freeze-up at this station was the first week in December; times varied from the second week in November through the third week in December. The average time of maximum ice thickness was the third week in February; times varied from the first week in February through the first week in March. Maximum ice thickness averaged 53 cm, varying from 38 cm to 69 cm. The average time of breakup was the last week in March; times varied from the third week in March through the third week in April.

Ice growth rates at this station averaged 7 mm/day; dissipation rates averaged 13 mm/day. The number of days from freeze-up to maximum ice thickness averaged 74 days (a 51-113 day range), and from maximum ice thickness to breakup, 41 days (a 27-54 day range). Ice cover duration averaged 115 days and varied from 100 days to 146 days.

White ice averaged 23 percent of total ice and varied from 9 percent to 35 percent. Figure 16 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice.

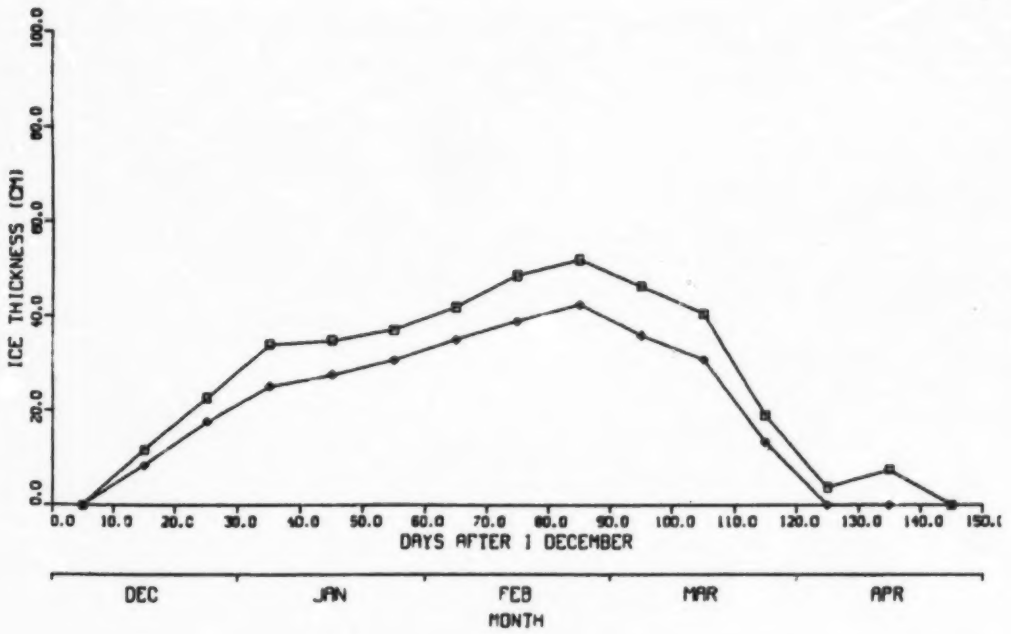

Figure 16.--Average total ice and clear ice thicknesses at Green Bay for 1965-79.

2.5.2 Menominee

The Menominee station (45°06'N, 87°36'W) is in Green Bay offshore of the city of Menominee, which lies near the middle of the western shore of Green Bay. Water depth is about 4.5-6.0 m. The station can be considered a companion station to Green Bay and Escanaba for comparison purposes.

The average time of freeze-up for Menominee was the first week in January; nearly the same as for Escanaba but a full month later than for Green Bay. Freeze-up varied only from the second week in December through the second week in January. The average time of maximum ice thickness was the second week in March; times varied from the third week in February through the last week in March. Maximum ice thickness averaged 59 cm, varying from 48 cm to 74 cm. Only two usable ice breakup dates (in the second and third weeks of April) were recorded.

Ice growth rates at this station averaged 9 mm/day, while dissipation rates averaged 26 mm/day. The number of days from freeze-up to maximum ice thickness averaged 68 days (a 49-85 day range), and from maximum ice thickness to breakup, 22 days. Ice cover duration averaged 90 days.

White ice averaged only 5 percent of total ice and varied from 0 percent to 21 percent. Figure 17, a plot of average total and clear ice thicknesses at this station, shows that, as at Escanaba, there is little white ice at this station. The area between the two curves is the average thickness of white ice.

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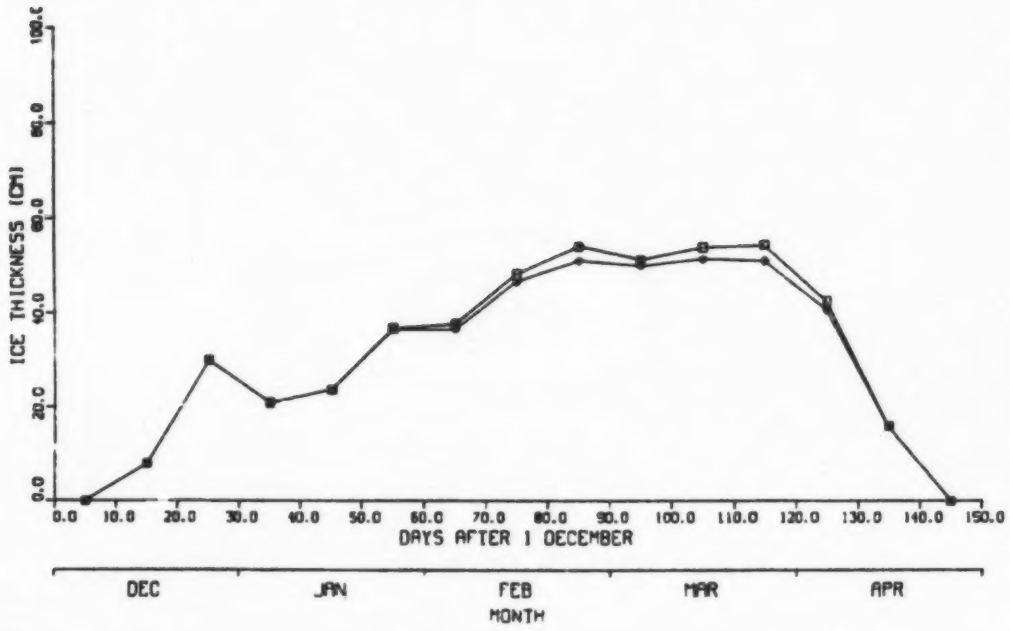

Figure 17.--Average total ice and clear ice thicknesses at Menominee for 1965-79.

2.5.3 Escanaba

The Escanaba station (45°45'N, 87°03'W) is near the area where Lake Michigan joins Green Bay, just offshore from the city of Escanaba. It lies over about 14.0 m of water.

The average time of freeze-up at this station was the last week in December; times varied from the second week in December through the second week in January. The average time of maximum ice thickness was the third week in February, times varied from the last week in January through the second week in March. Maximum ice thickness averaged 62 cm, varying from 48 cm to 86 cm.

Ice growth rates at this station averaged 11 mm/day. The number of days from freeze-up to maximum ice thickness averaged 55 days (a 42-72 day range). Because of a lack of data on breakup dates, statistics for breakup and duration were not computed.

White ice averaged only 5 percent of total ice and varied from 0 percent to 16 percent. Figure 18 shows average total and clear ice thicknesses at this station. Possibly, the rather abrupt decrease in thickness of the ice cover is a reflection of the lack of data. The area between the two curves is the average thickness of white ice.

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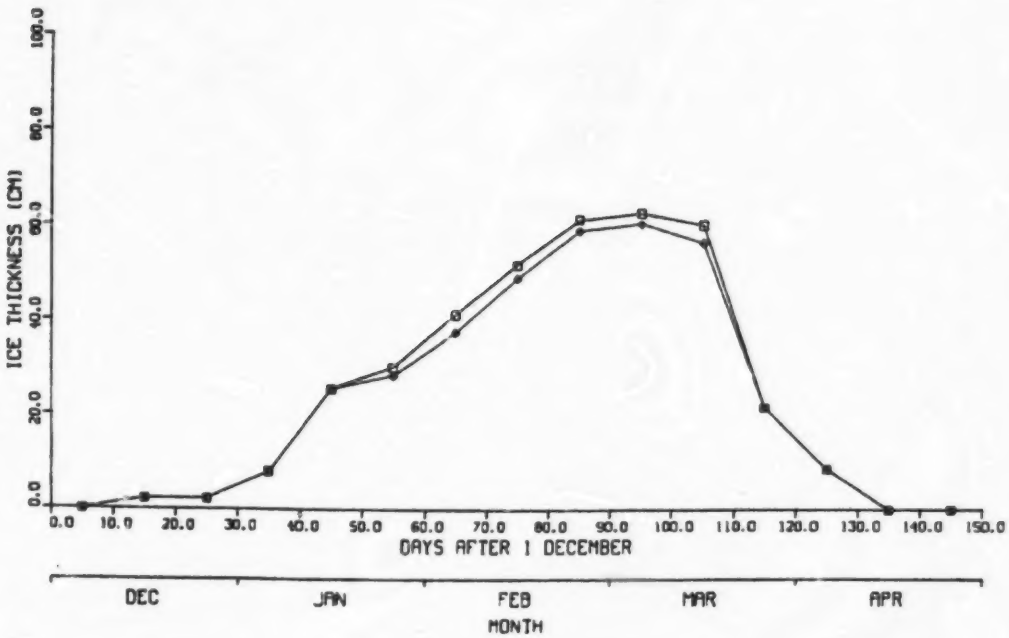

Figure 18.--Average total ice and clear ice thicknesses at Escanaba for 1965-79.

2.5.4 Muskegon Lake-Snug Harbor

The Muskegon Lake station (43°15'N, 86°20'W) is on an inland lake near the Lake Michigan shore. Measurements were taken at Snug Harbor at the northern end of the lake in an area over 2.5-4.5 m of water.

The average time of freeze-up at this station (based on only four observations) was the last week in December, varying from the second week in December through the second week in January. The average time of maximum ice thickness was the second week in February, times varied from the second week in January through the first week in March. Maximum ice thickness averaged 33 cm, varying from 23 cm to 45 cm. The average time of breakup was the first week in April; times varied from the third week in March through the second week in April.

Ice growth rates at this station averaged 6 mm/day; dissipation rates averaged only 7 mm/day. The number of days from freeze-up to maximum ice thickness averaged 52 days (a 37-73 day range), and from maximum ice thickness to breakup, 46 days (a 33-63 day range). Ice cover duration averaged 98 days (based on four cases) and varied from 87 days to 119 days.

White ice averaged 35 percent of total ice and varied from 12 percent to 59 percent. This is high with respect to other Lake Michigan stations; that is probably because the station is on the eastern side of Lake Michigan and, thus, subject to lake effect snowfall. Figure 19 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice.

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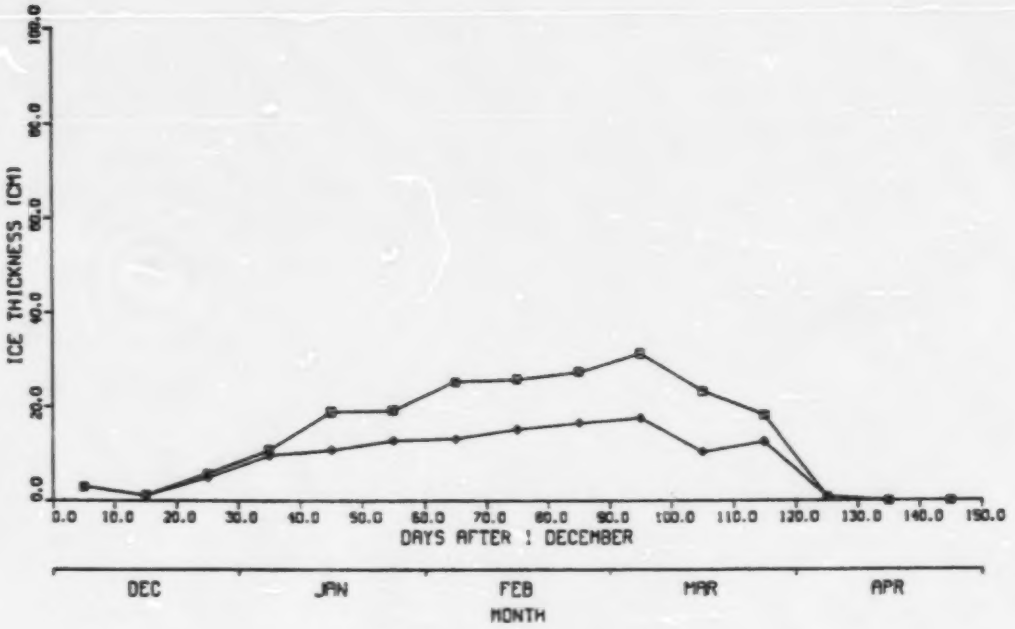

Figure 19.--Average total ice and clear ice thicknesses at Muskegon Lake-Snug Harbor for 1965-79.

2.6 Lake Huron

Seven reporting stations are included in the Lake Huron analysis, including two in the St. Marys River (Fig. 1). The average time of freeze-up for all stations was the last week in December. The average time of freeze-up at individual stations varied from the second week in December at Raber Bay (St. Marys River) and Wigwam Bay (Saginaw Bay) through the second week in January at Mackinaw City, Mich. Perhaps freeze-up at Raber Bay is early because relatively cool Lake Superior water passes down the St. Marys River and because there is little turbulent water at the station. Perhaps freeze-up at the Straits of Mackinac is late because relatively warm Lake Michigan water passes through the straits. Ice thickness reached a maximum (whole-lake average) in the last week in February. Average ice thicknesses for individual stations reached a maximum as early as the second week in February at Alpena, Mich., and as late as the second week in March at Lake Munuscong and Raber Bay--the two northernmost stations. Maximum ice thickness averaged 54 cm for all stations and varied from an average of 37 cm at Alpena to 67 cm at Raber Bay. The average breakup date for all stations was in the first week in April. It is not surprising that this date is so close to the average date for Lake Michigan breakup since most of the Lake Huron stations are in roughly the same latitude band as those in Lake Michigan. The average breakup date at individual stations varied from the second week in March at Alpena to the third week in April at all of the northernmost stations in the network (Lake Munuscong, Raber Bay, and St. Martin Bay).

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The average ice growth rate for all Lake Huron stations was the same as for Lakes Superior and Michigan (8 mm/day). The highest average growth rate (11 mm/day) was found at Mackinaw City, and the lowest (7 mm/day) at Lake Munuscong and Raber Bay. The average ice dissipation rate for all stations was 17 mm/day. Average ice dissipation rates for individual stations varied from 14 mm/day at Lake Munuscong, St. Martin Bay, and Mackinaw City to 28 mm/day at Alpena. Average whole-lake ice duration was 101 days, nearly the same as for Lake Michigan. Average ice durations varied from 66 days at Alpena to 132 days at Raber Bay.

White ice as a percentage of total ice averaged 17 percent for all stations. The lowest average of white ice (7 percent) was recorded at St. Martin Bay and the highest (25 percent) at Lake Munuscong. High ratios of white ice to total ice were also indicated at Raber Bay and Mackinaw City. It is interesting that high and low percentages of white ice occurred only a few miles from each other, across the Straits of Mackinac, at St. Martin Bay and Mackinaw City. Analysis of data for individual stations follows.

2.6.1 Lake Munuscong

The Lake Munuscong station (46°13'N, 84°10'W) is in a bay of the St. Marys River, north of De Tour, Mich., and directly west of St. Joseph Island. It is near the shipping channel over 1.5-3.0 m of water. Raber Bay just to the south is a companion station.

The average time of freeze-up at this station was the third week in December; times varied from the first week in December through the second week in January. The average time of maximum ice thickness was the second week in March; times varied from the first week in March through the last week in March. Maximum ice thickness averaged 60 cm, varying from 45 cm to 76 cm. The average time of breakup was the third week in April; times varied from the first week in April through the first week in May (based on only three cases). Ice growth rates at this station averaged 7 mm/day; dissipation rates averaged 14 mm/day. The number of days from freeze-up to maximum ice thickness averaged 82 days (a 63-92 day range), and from maximum ice thickness to breakup, 42 days (a 28-63 day range). Ice cover duration averaged 124 days and varied from 113 days to 126 days.

White ice averaged 25 percent of total ice and varied from 17 percent to 35 percent. Figure 20, a plot of average total and clear ice thicknesses at this station, shows a rather smooth progression of ice growth. The area between the two curves is the average thickness of white ice.

2.6.2 Raber Bay

The Raber Bay station (46°06'N, 84°03'W) is west of Lime Island near the shore in the St. Marys River over about 3.0 m of water. It is much closer to the shore than to the shipping channel--the opposite of the situation for the companion Lake Munuscong station just to the north.

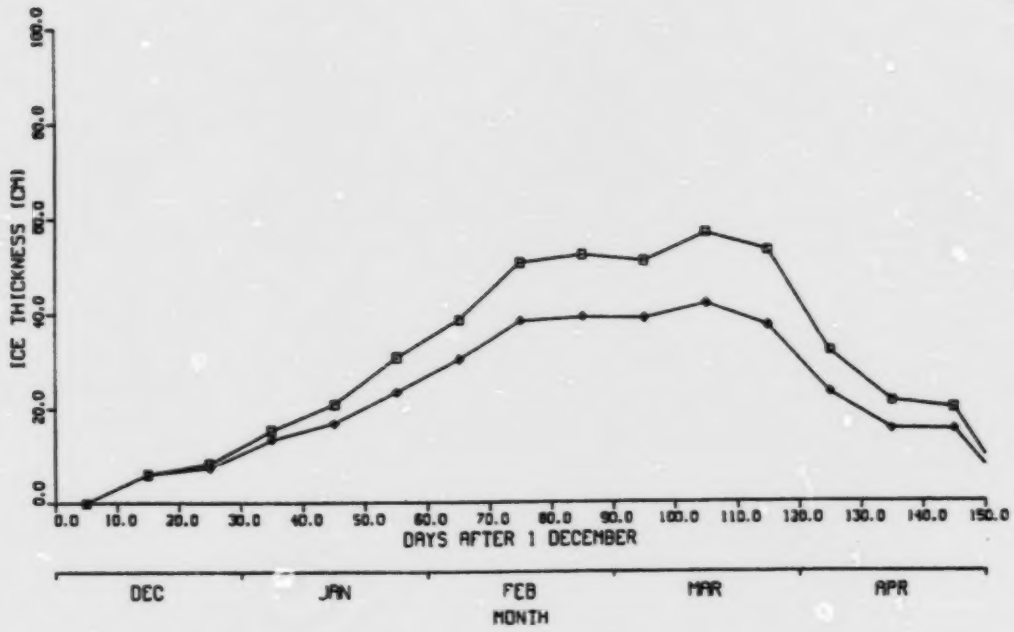

Figure 20.--Average total ice and clear ice thicknesses at Lake Munuscong for 1965-79.

The average freeze-up date at this station was the second week in December; times varied widely from the third week in November through the last week in January. The average time of maximum ice thickness was the second week in March; times varied from the second week in February through the last week in March. Maximum ice thickness averaged 67 cm, varying from 50 cm to 81 cm. The average time of breakup was the third week in April; times varied from the first week in April through the first week in May.

Ice growth rates at this station averaged 7 mm/day; dissipation rates averaged 16 mm/day. The number of days from freeze-up to maximum ice thickness averaged 91 days (a 42-112 day range), and from maximum ice thickness to breakup, 41 days (a 27-67 day range). Ice cover duration averaged 132 days and varied from 88 days to 157 days.

White ice averaged 24 percent of total ice and varied from 8 percent to 33 percent. Figure 21, a plot of average total and clear ice thicknesses at this station, shows many similarities to the plot for the nearby Lake Munuscong station. The area between the two curves is the average thickness of white ice.

2.6.3 St. Martin Bay

The St. Martin Bay station (46°01'N, 84°41'W) is on the main body of Lake Huron near the Straits of Mackinac. It is directly west of Charles, Mich., in a bay sheltered from the main portion of Lake Huron by two islands. Water depth at the station is about 6.0 m.

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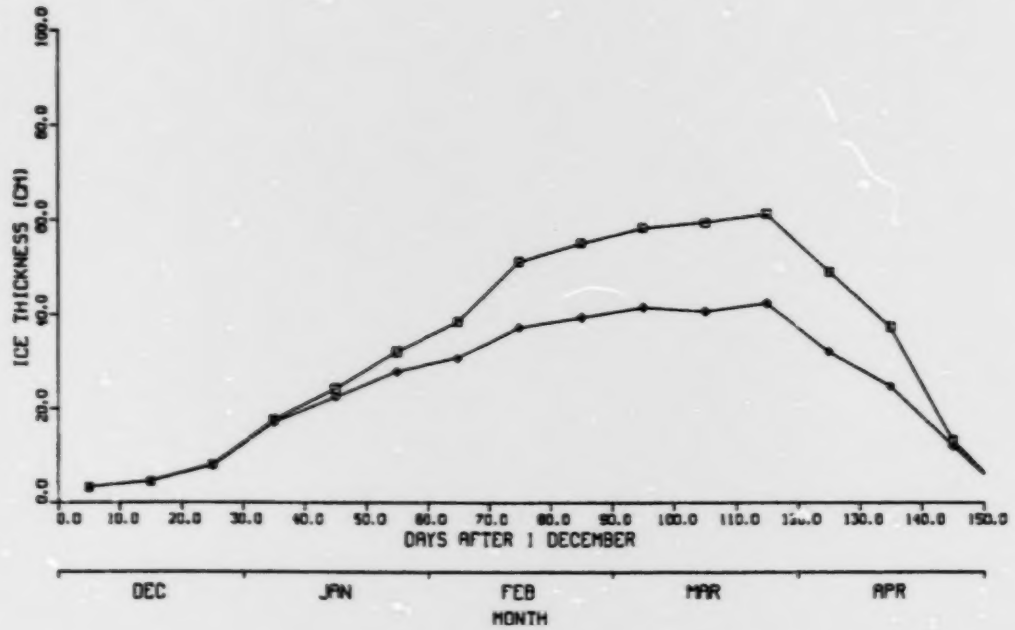

Figure 21.--Average total ice and clear ice thicknesses at Raber Bay for 1965-79.

The average time of freeze-up at this station was the last week in December; times varied from the first week in December through the second week in January. The average time of maximum ice thickness was the first week in March; times varied from the third week in February through the last week in March. Maximum ice thickness averaged 53 cm, varying from 43 cm to 64 cm. The average time of breakup was the third week in April; times varied from the first week in April through the last week in April.

Ice growth rates at this station averaged 9 mm/day; dissipation rates averaged 14 mm/day. The number of days from freeze-up to maximum ice thickness averaged 69 days (a 52-98 day range), and from maximum ice thickness to breakup, 46 days (a 32-60 day range). Ice cover duration averaged 115 days and varied from 95 days to 137 days.

White ice averaged only 7 percent of total ice and varied from 2 percent to 12 percent. Figure 22, a plot of average total and clear ice thicknesses at this station, shows a rather extended ice season with only small amounts of white ice. The area between the two curves is the average thickness of white ice.

2.6.4 Mackinaw City

The Mackinaw City station (45°46'N, 84°43'W) is on the Straits of Mackinac, about 400 m east of the Mackinac Bridge. Although the station is near the shore, the water depth is between 15.0 and 18.0 m.

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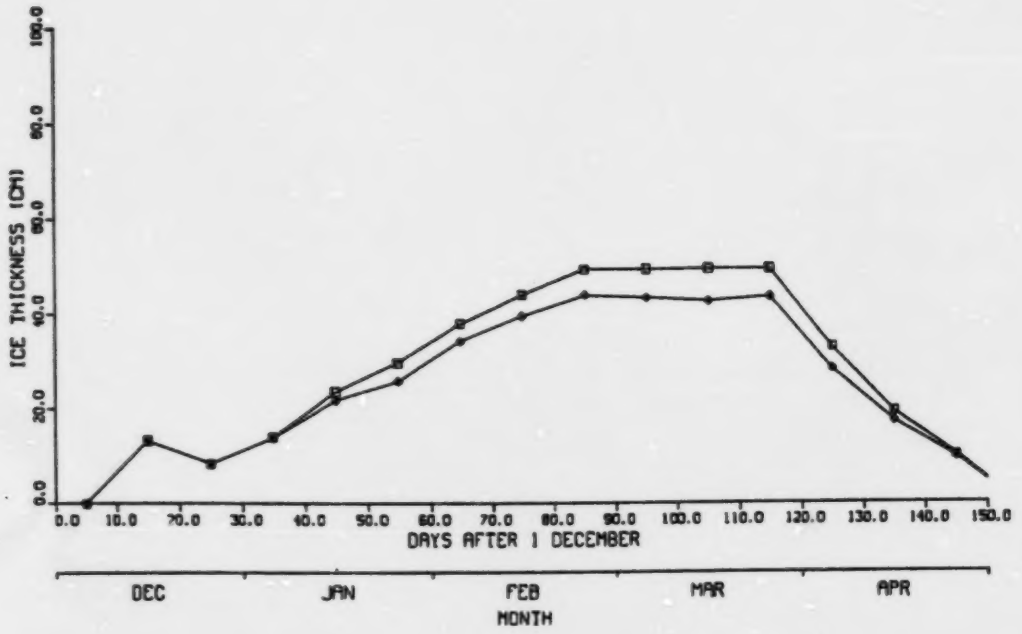

Figure 22.--Average total ice and clear ice thicknesses at St. Martin Bay for 1965-79.

The average time of freeze-up at this station was the second week in January; times varied from the last week in December through the last week in January. The average time of maximum ice thickness was the last week in February; times varied from the second week in February through the second week in March. Maximum ice thickness averaged 50 cm, varying from 33 cm to 64 cm. The average time of breakup date was the last week in March; times varied from the third week in March through the second week in April.

Ice growth rates at this station averaged 11 mm/day; dissipation rates averaged 14 mm/day. The number of days from freeze-up to maximum ice thickness averaged 44 days (a 23-57 day range), and from maximum ice thickness to breakup, 34 days (an 18-46 day range). Ice cover duration averaged 78 days and varied from 63 days to 96 days.

White ice averaged 24 percent of total ice and varied from 16 percent to 28 percent. Figure 23, a plot of average total and clear ice thicknesses at this station, shows that Mackinaw City averaged a shorter ice season than nearby St. Martin Bay. The area between the two curves is the average thickness of white ice. Figure 24 shows the range of total ice thicknesses and freeze-up and breakup dates to highlight the variability in freeze-up and breakup dates at this station.

2.6.5 Thunder Bay

The Thunder Bay station (45°03'N, 83°26'W) is near Alpena over 3.0-4.5 m of water in the sheltered area of the bay between North Point and Partridge Point. Although open to Lake

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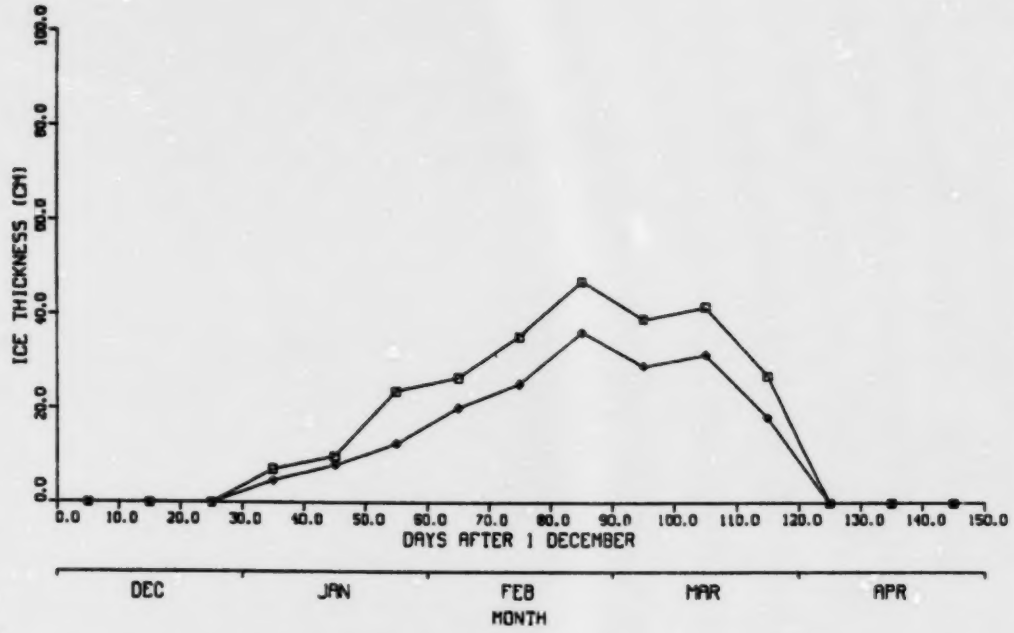

Figure 23.--Average total ice and clear ice thicknesses at Mackinaw City for 1965-79.

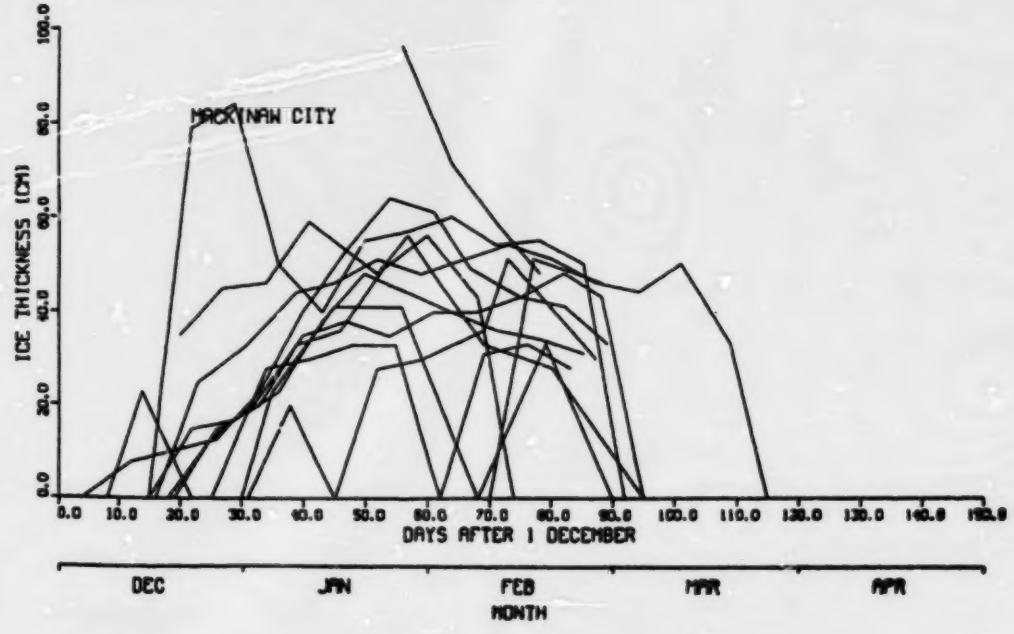

Figure 24.--Total ice thicknesses recorded at Mackinaw City from 1965-79.

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Huron, the entire bay is sheltered from all but southeasterly winds. Data at the station often appeared erratic, indicating possible observation problems. During quality control, no specific problems could be found, indicating that undetected natural factors possibly influenced the ice thickness. This should be kept in mind as the statistics are used.

The average time of freeze-up at this station was the last week in December; times varied from the last week in November through the second week in January. The average time of maximum ice thickness was the second week in February; times varied from the first week in January through the last week in February. Maximum ice thickness averaged 37 cm, varying from 15 cm to 92 cm. The average time of breakup (based on only three dates) was the second week in March; times varied from the last week in February through the last week in March.

Ice growth rates at this station averaged 8 mm/day; dissipation rates averaged 28 mm/day. The number of days from freeze-up to maximum ice thickness averaged 47 days (an 11-87 day range), and from maximum ice thickness to breakup, 19 days (a 5-32 day range). Ice cover duration, based on limited data, averaged 66 days and varied from 62 days to 119 days.

White ice averaged 18 percent of total ice and varied from 0 percent to 49 percent. Figure 25, a plot of average total and clear ice amounts at this station, shows low total ice values for a station at this high a latitude. The area between the two curves is the average thickness of white ice.

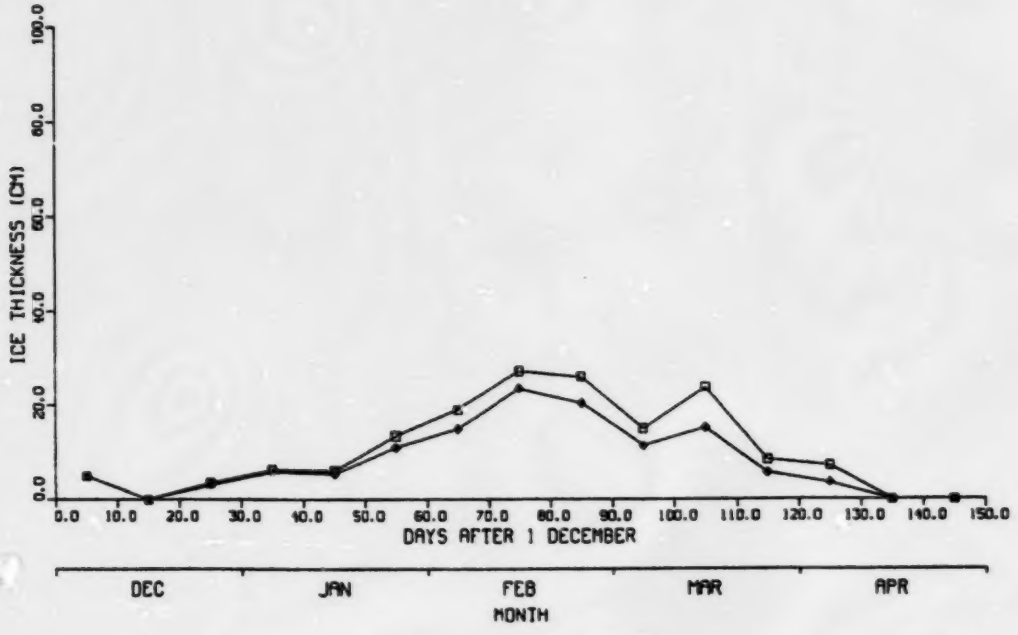

Figure 25.--Average total ice and clear ice thicknesses at Thunder Bay for 1965-79.

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2.6.6 Point Lookout-Saginaw Bay

The Point Lookout station (44°02'N, 83°36'W) is at the mouth of Saginaw Bay; it is slightly protected from the main body of Lake Huron by a small point of land. Water depth is about 1.5-3.0 m. A nearby station, Wigwam Bay (43°59'N, 83°49'W), can be used for comparison purposes.

The average time of freeze-up at this station was the last week in December; times varied from the first week in December through the second week in January. The average time of maximum ice thickness was the third week in February; times varied from the last week in January through the second week in March. Maximum ice thickness averaged 46 cm, varying from 31 cm to 74 cm. The average time of breakup was the last week in March; times varied from the third week in February through the third week in April.

Ice growth rates at this station averaged 8 mm/day; dissipation rates averaged 16 mm/day. The number of days from freeze-up to maximum ice thickness averaged 58 days (a 35-78 day range), and from maximum ice thickness to breakup, 31 days (a 7-56 day range). Ice cover duration averaged 89 days and varied from 63 days to 110 days.

White ice averaged only 9 percent of total ice and varied from 0 percent to 19 percent. Figure 26, a plot of average total and clear ice thicknesses at this station, shows little white ice and rather thick ice cover for this latitude. The area between the two curves is the average thickness of white ice.

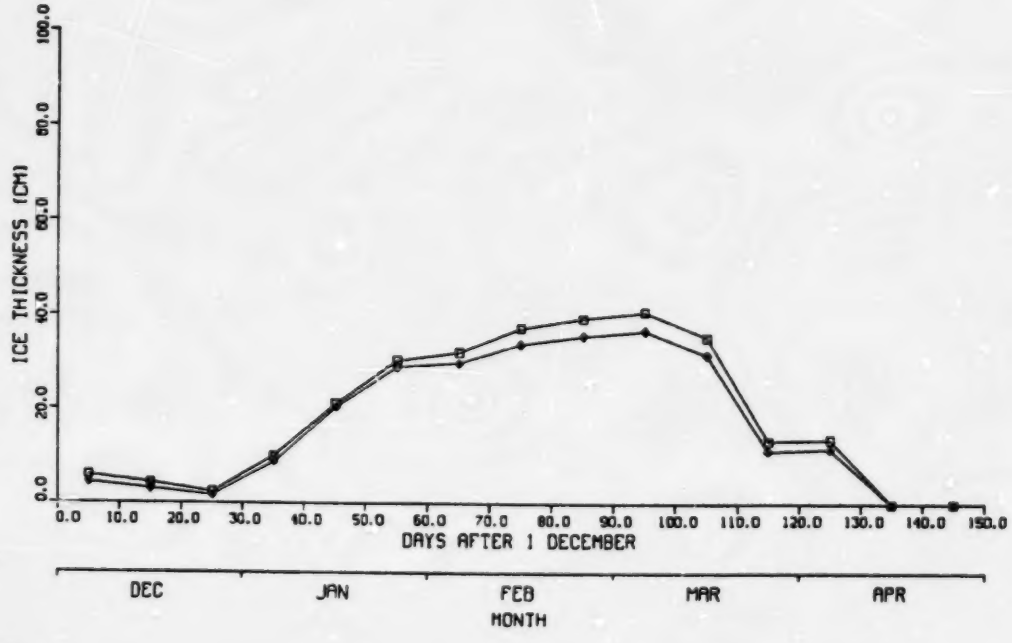

Figure 26.--Average total ice and clear ice thicknesses at Point Lookout for 1965-79.

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2.6.7 Wigman Bay-Saginaw Bay

The Wigman Bay station (43°59'N, 83°49'W) is near the north shore of Saginaw Bay to the west of Point au Gres. It is close to the Point Lookout station, but more toward the interior of the bay. Water depth at the station is only about 1.5 m.

The average time of freeze-up date at this station was the second week in December; times varied from the last week in November through the third week in December. The average time of maximum ice thickness was the last week in February; times varied from the last week in January through the second week in March. Maximum ice thickness averaged 58 cm, varying from 40 cm to 84 cm. The average time of breakup was the third week in March; times varied from the second week in March through the first week in April.

Ice growth rates at this station averaged 8 mm/day; dissipation rates averaged 18 mm/day. The number of days from freeze-up to maximum ice thickness averaged 71 days (a 49-92 day range), and from maximum ice thickness to breakup, 30 days (a 13-62 day range). Ice cover duration averaged 101 days and varied from 98 days to 112 days.

White ice averaged 14 percent of total ice and varied from 7 percent to 23 percent. Figure 27, a plot of average total and clear ice thicknesses at this station, shows that ice is thicker here than at the nearby Point Lookout station, possibly because this station is sheltered. The area between the two curves is the average thickness of white ice.

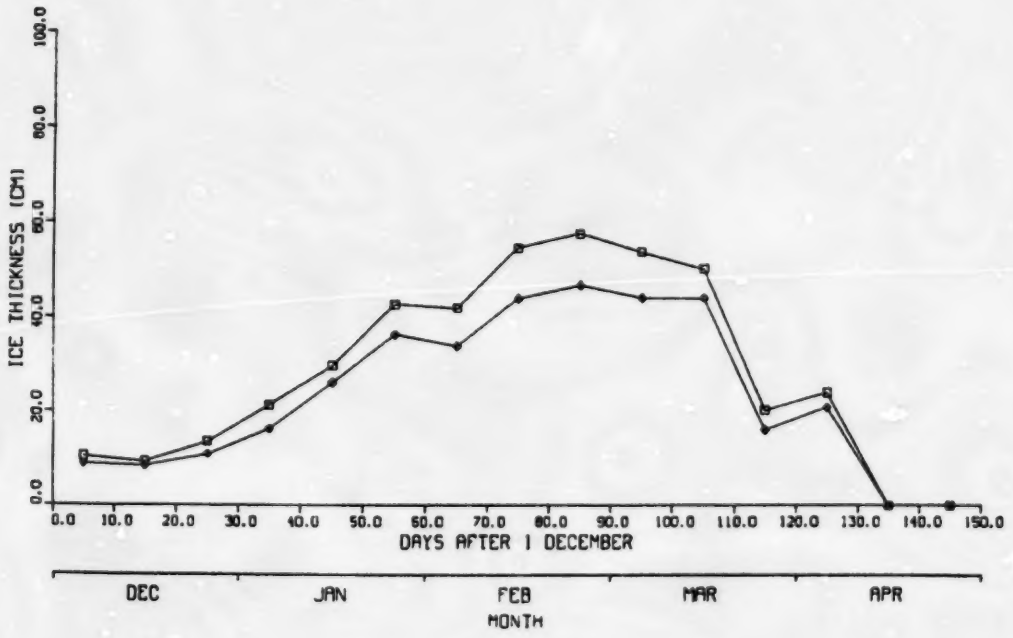

Figure 27. Average total ice and clear ice thicknesses at Wigwam Bay for 1965-79.

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2.7 Lakes Erie/St. Clair

Four reporting stations are included in the Lakes Erie/St. Clair analysis (Fig. 1). The average time of freeze-up for all stations was the last week in December. No large variance of average freeze-up dates was noted between individual stations. The average time of freeze-up at individual stations varied from the third week in December at Brest Bay through the last week in December at all other stations. Dates of maximum ice amounts showed a similar lack of variation. Ice thickness reached a maximum (whole-lake average) in the first week in February. Average ice thicknesses for a particular station reached a maximum as early as the last week in January at Brest Bay and as late as the second week in February at New Baltimore, Mich., on Lake St. Clair. Maximum ice thickness averaged 33 cm for all stations and varied from 29 cm at New Baltimore to 35 cm at Brest Bay. Average breakup dates varied little from station to station. The average breakup date for all stations was in the second week in March. The average breakup date at individual stations varied from the first week in March at Marblehead, Ohio, to the second week in March at Marine Lake, Brest Bay, and New Baltimore. Probably the freeze-up, breakup, and maximum ice dates vary so little because of heat budget factors associated with Lakes Erie/St. Clair, which are very shallow compared with the other Great Lakes.

Ice growth rate for all stations averaged 8 mm/day. That is the same as the Lakes Superior, Michigan, and Huron averages. The lowest average growth rate (6 mm/day) was found at New Baltimore, and the highest (9 mm/day) at Marblehead. The average ice dissipation rate for all stations was 11 mm/day, which is the lowest for all of the Great Lakes. Average ice dissipation rates for individual stations varied from 9 mm/day at New Baltimore on Lake St. Clair to 12 mm/day at Marine Lake. Average whole-lake ice duration was 74 days. Average ice duration was considerably lower than for any of the other Great Lakes, varying from 64 days at Marblehead to 83 days at Brest Bay. White ice as a percentage of total ice averaged only 7 percent for all stations, the lowest percentage for all of the Great Lakes. The lowest average of white ice (2 percent) was recorded at Brest Bay, and the highest (14 percent) at Marblehead. Analysis of data for individual stations follows.

2.7.1 Marine Lake-Erie Harbor

The Marine Lake station (42°08'N, 80°08'W) is near the dock area of the Presque Isle State Park Marina. It is sheltered from the waves of Lake Erie. Water depth at the station is less than 3.0 m.

The average time of freeze-up at this station was the last week in December; times varied from the first week in December through the third week in January. The average time of maximum ice thickness was the first week in February; times varied from the second week in January through the last week in February. Maximum ice thickness averaged 32 cm, varying from 15 cm to 61 cm. The average time of breakup was the second week in March; times varied from the last week in February through the third week in March.

Ice growth rates at this station averaged 8 mm/day; dissipation rates averaged 12 mm/day. The number of days from freeze-up to maximum ice thickness averaged 42 days (a 28-70 day range), and from maximum ice thickness to breakup, 27 days (an 11-68 day range). Ice cover duration averaged 69 days and varied from 39 days to 105 days.

White ice averaged only 8 percent of total ice and varied from 0 percent to 30 percent. Figure 28 shows low total and clear ice thicknesses at this station but a surprisingly lengthy ice season. The area between the two curves is the average thickness of white ice.

2.7.2 Marblehead-Catawba Island

The Marblehead station (41°33'N, 82°52'W) is directly north of the town of Catawba Island and southwest of Mouse Island. It is exposed to the main body of Lake Erie. Water depth at the station is 4.5-6.0 m.

The average time of freeze-up at this station was the last week in December; times varied from the first week in December through the second week in January. The average time of maximum ice thickness was the first week in February; times varied from the second week in January through the third week in February. Maximum ice thickness averaged 34 cm, varying from 10 cm to 71 cm. The average time of breakup was the first week in March; times varied from the second week in February through the third week in March.

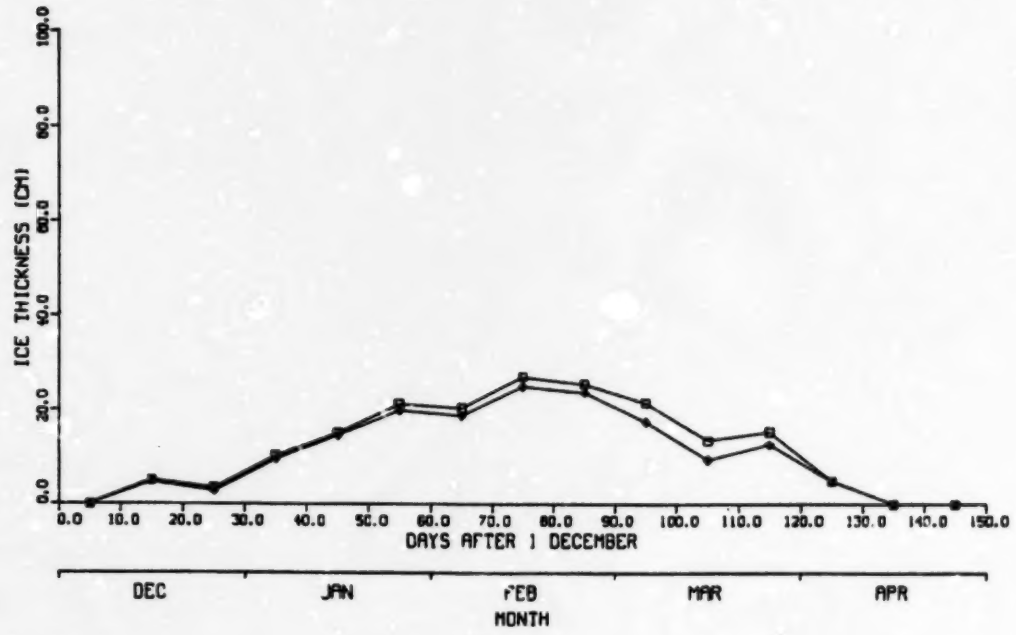

Figure 28.--Average total ice and clear ice thicknesses at Marine Lake-Erie Harbor for 1965-79.

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Ice growth rates at this station averaged 9 mm/day; dissipation rates averaged 12 mm/day. The number of days from freeze-up to maximum ice thickness averaged 37 days (a 21-63 day range), and from maximum ice thickness to breakup, 29 days (an 11-46 day range). Ice cover duration averaged 66 days and varied from 33 days to 101 days.

White ice averaged 14 percent of total ice and varied from 0 percent to 32 percent. Figure 29 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice.

2.7.3 Brest Bay

The Brest Bay station (41°55'N, 83°19'W) is near Monroe, Mich., and the Raisin River at the western end of Lake Erie. Water depths near the station vary from 2.5 to 5.5 m.

The average time of freeze-up at this station was the third week in December; times varied from the last week in November through the first week in January. The average time of maximum ice thickness was the last week in January; times varied from the second week in January through the third week in February. Maximum ice thickness averaged 35 cm, varying from 15 cm to 61 cm. The average time of breakup was the second week in March; times varied from the first week in March through the third week in March.

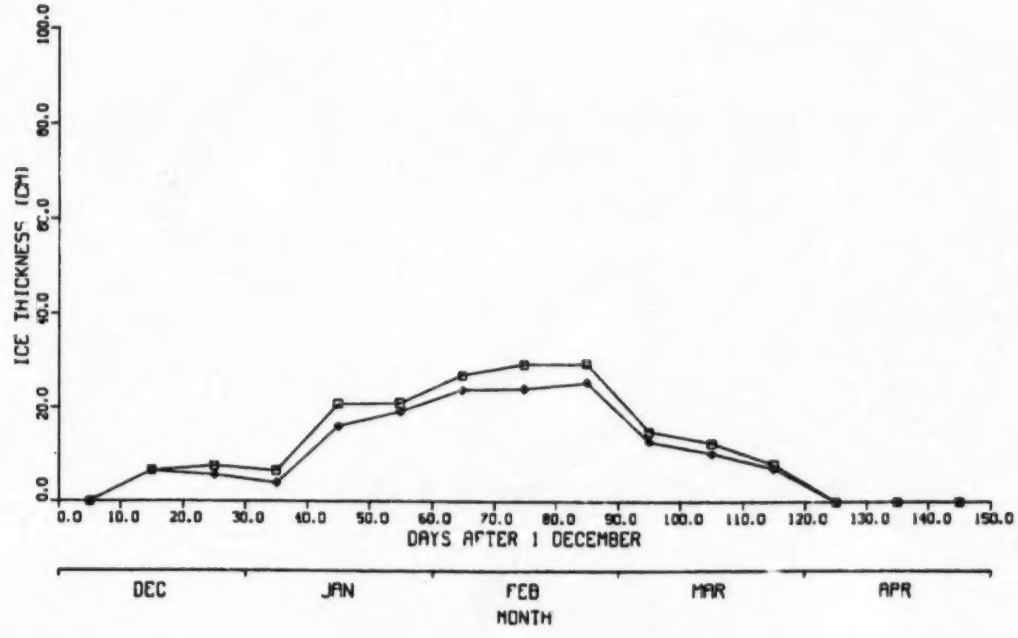

Figure 29.--Average total ice and clear ice thicknesses at Marblehead-Catawba Island for 1965-79.

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Ice growth rates at this station averaged 8 mm/day; dissipation rates averaged 10 mm/day. It is interesting to note that these figures are very close to those for more northerly stations, such as Mosquito Bay on the St. Marys River. The number of days from freeze-up to maximum ice thickness averaged 43 days (a 35-63 day range), and from maximum ice thickness to breakup, 40 days (a 28-48 day range). Ice cover duration averaged 83 days (based on three cases) and varied from 63 days to 107 days.

White ice was nearly nonexistent at this station, averaging 2 percent of the total ice and varying from 0 percent to 14 percent. Figure 30, a plot of average total and clear ice thicknesses at this station, shows very little white ice. The area between the two curves is the average thickness of white ice.

2.7.4 New Baltimore-Lake St. Clair

The New Baltimore-Lake St. Clair station (42°40'N, 82°43'W) is southeast of the town of New Baltimore on Lake St. Clair. Water depth is about 1.5-3.0 m.

The average time of freeze-up at this station was the fourth week in December; times varied from the third week in December through the third week in January. The average time of maximum ice thickness was the second week in February; times varied from the second week in January through the second week in March. Maximum ice thickness averaged 29 cm, varying from 5 cm to 49 cm. The average time of breakup was the second week in March; times varied from the last week in February through the last week in March.

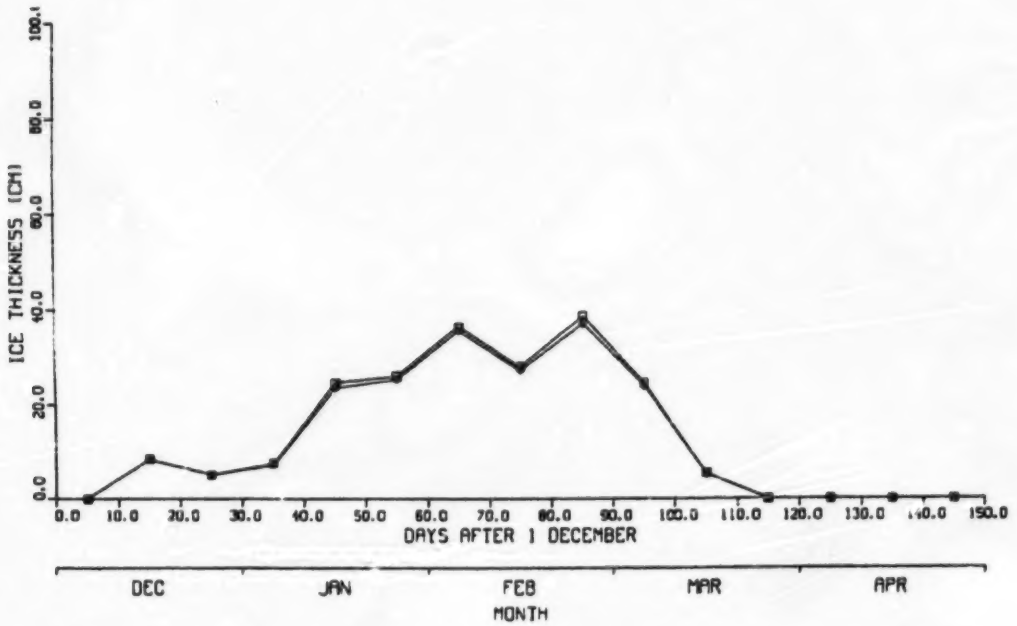

Figure 30.--Average total ice and clear ice thicknesses at Brest Bay for 1965-79.

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Ice growth rates at this station averaged 6 mm/day; dissipation rates averaged 9 mm/day. The number of days from freeze-up to maximum ice thickness averaged 49 days (a 25-70 day range), and from maximum ice thickness to breakup, 26 days (a 9-69 day range). Ice cover duration averaged 75 days and varied from 43 days to 94 days.

White ice averaged only 5 percent of total ice and varied from 0 percent to 16 percent. Figure 31, a plot of average total and clear ice thicknesses for this station, shows little white ice. The area between the two curves is the average thickness of white ice.

2.8 Lake Ontario

Four reporting stations are included in the Lake Ontario analysis (Fig. 1). The average time of freeze-up for all stations was the same as for all the other Great Lakes--the last week in December. The average time of freeze-up at individual stations varied widely, from the second week in December at North Pond through the second week in January at Wilson Bay. Ice thickness reached a maximum (whole-lake average) in the third week in February. Average ice thicknesses for a particular station reached a maximum as early as the second week in February at North Pond and as late as the last week in February at Wilson Bay. Maximum ice thickness averaged 42 cm for all stations and varied from 42 cm at Rochester, N.Y., to 50 cm at Wilson Bay. The average date of breakup for all stations was in the first week in April. Average breakup dates at individual stations varied only from the last week in March at Rochester and Wilson Bay through the second week in April at Henderson Harbor.

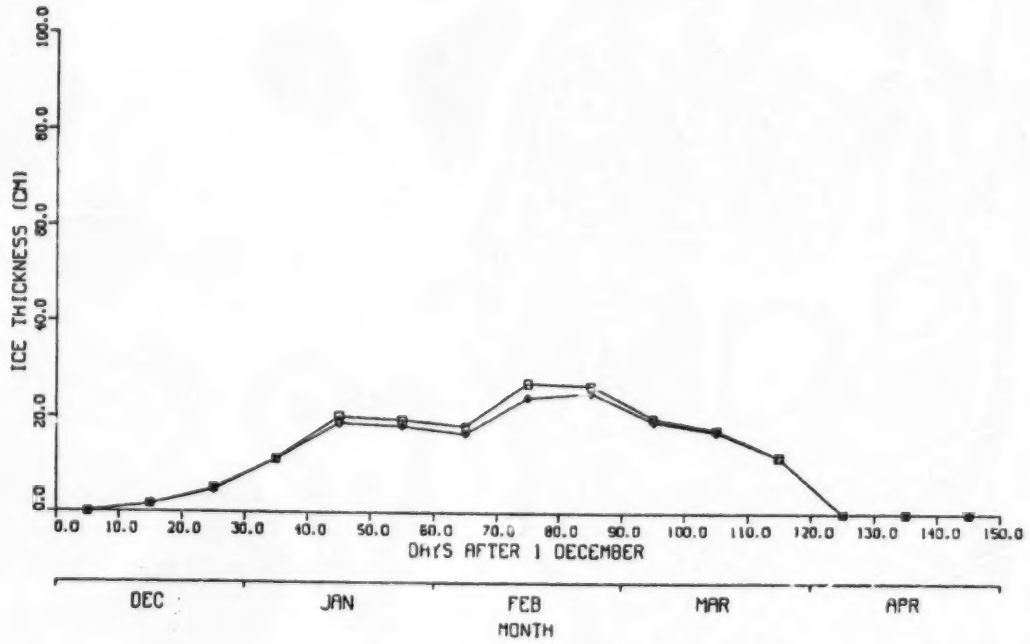

Figure 31.--Average total ice and clear ice thicknesses at New Baltimore for 1965-79.

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Ice growth rates for all stations averaged 9 mm/day. The lowest average growth rate (7 mm/day) was found at Rochester and North Pond, and the highest (13 mm/day) at Wilson Bay. As with the average growth rate, the average ice dissipation rate for all stations (12 mm/day) was higher than the Lake Erie average. Average ice dissipation rates for individual stations varied from a very low rate--9 mm/day--at Rochester to a rather high rate--17 mm/day--at Wilson Bay. Average whole-lake ice duration was 91 days, varying from 64 days at Wilson Bay to 116 days at North Pond. The short duration at Wilson Bay is probably due to the rather late freeze-up at that location possibly caused by the influence of the upper St. Lawrence River.

White ice as a percentage of total ice averaged a respectable 21 percent for all stations. It should be noted, however, that all the stations are in areas where significant lake effect snowfalls are possible. The lowest average of white ice (15 percent) was recorded at Henderson Harbor, and the highest (29 percent) at Rochester. Analysis of data for individual stations follows.

2.8.1 Wilson Bay

The Wilson Bay station (44°05'N, 76°21'W) is to the southwest of Cape Vincent, N.Y., at the mouth of the St. Lawrence River. The bay is fairly sheltered, protected by Wilson Point to the north and Dablon Point to the south. The station is at the north side of the bay over about 3.0 m of water.

The average time of freeze-up at this station was the second week in January; times varied from the last week in December through the last week in January. The average time of maximum ice thickness was the last week in February; times varied from the first week in February through the third week in March. Maximum ice thickness averaged 50 cm, varying from 30 cm to 87 cm. The average time of breakup was the last week in March; times varied from the second week in March through the first week in April.

Ice growth rates at this station averaged 13 mm/day; dissipation rates averaged 17 mm/day. The number of days from freeze-up to maximum ice thickness averaged 39 days (a 16-57 day range), and from maximum ice thickness to breakup, 25 days (a 14-42 day range). Ice cover duration averaged 63 days and varied from 43 days to 78 days.

White ice averaged 18 percent of total ice and varied from 0 percent to 38 percent. Figure 32 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice. Comparing Figure 34 with Figure 32 shows that this station has a considerably shorter ice season than another Lake Ontario station, North Pond.

2.8.2 Henderson Harbor

The Henderson Harbor station (42°52'N, 76°13'W) is at the southeast end of Henderson Bay in Lake Ontario. The area is sheltered from the main force of westerly Lake Ontario winds, but winds from the northwest could easily affect the ice climatology. Water depths near the station vary from 1.5 to 4.5 m.

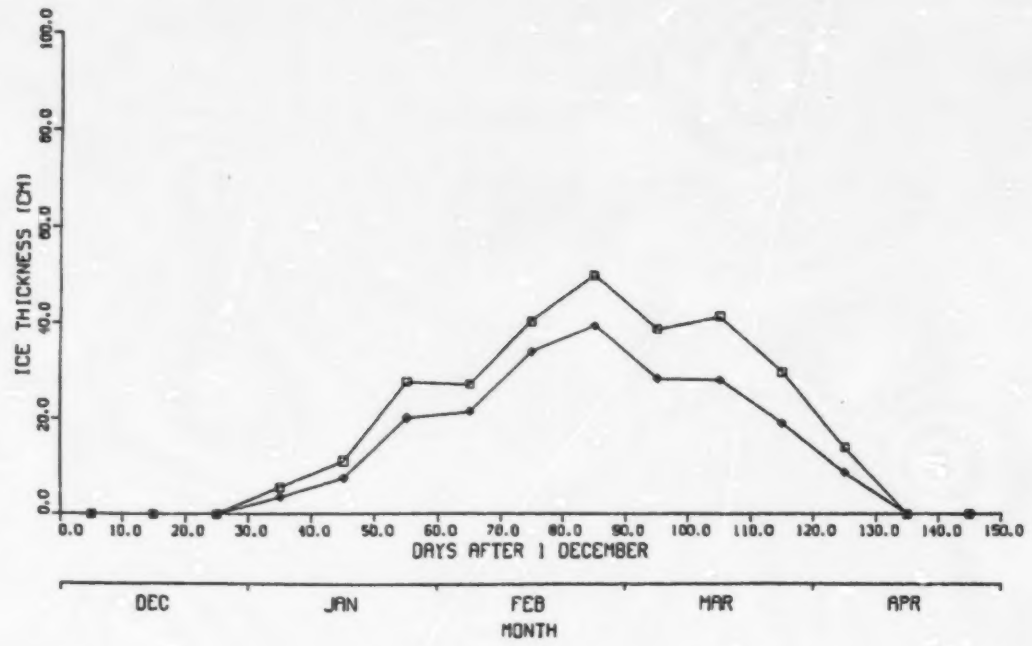

Figure 32.--Average total ice and clear ice thicknesses at Wilson Bay for 1965-79.

The average time of freeze-up at this station was the last week in December; times varied from the second week in December through the first week in January. The average time of maximum ice thickness was the third week in February; times varied from the second week in January through the second week in March. Maximum ice thickness averaged 44 cm, varying from 21 cm to 63 cm. The average time of breakup (based on only 3 years of data) fell during the second week in April; times varied from the last week in March through the third week in April.

Ice growth rates at this station averaged 9 mm/day; dissipation rates averaged 12 mm/day. The number of days from freeze-up to maximum ice thickness averaged 52 days (a 25-67 day range), and from maximum ice thickness to breakup, 48 days (a 40-55 day range). Ice cover duration averaged 100 days and varied from 89 days to 121 days.

White ice averaged only 15 percent of total ice and varied from 0 percent to 36 percent. Figure 33 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice.

2.8.3 North Pond

The North Pond station (43°39'N, 76°11'W) is on an inland body of water over slightly more than 3.0 m of water. There is a small inlet connecting the pond with Lake Ontario.

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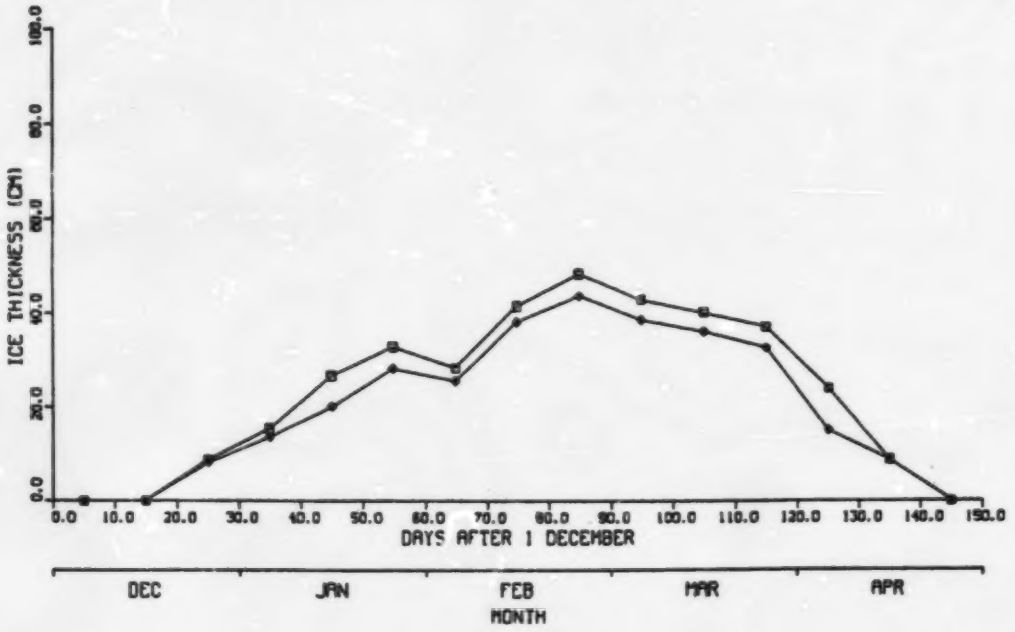

Figure 33.--Average total ice and clear ice thicknesses at Henderson Harbor for 1965-79.

The average time of freeze-up at this station was the second week in December; times varied from the last week in November through the last week in December. The average time of maximum ice thickness was the second week in February; times varied from the third week in January through the second week in March. Maximum ice thickness averaged 42 cm, varying from 35 cm to 53 cm. The average time of breakup was the first week in April; times varied from the last week in March through the last week in April.

Ice growth rates at this station averaged 7 mm/day; dissipation rates averaged 8 mm/day. The number of days from freeze-up to maximum ice thickness averaged 62 days (a 28-84 day range), and from maximum ice thickness to breakup, 54 days (a 40-68 day range). Ice cover duration averaged 116 days and varied from 100 days to 147 days.

White ice averaged 21 percent of total ice and varied from 0 percent to 44 percent. Figure 34, a plot of average total and clear ice thicknesses for this station, shows a moderate amount of white ice for this latitude, presumably because of strong lake effect snowfalls. The area between the two curves is the average thickness of white ice. Figure 35 shows the wide range of total ice thicknesses and of freeze-up and breakup dates at this station.

2.8.4 Irondequoit Bay-Rochester

The Rochester station (43°12'N, 77°31'W) is to the east of the city of Rochester on Irondequoit Bay. It is well sheltered from most of Lake Ontario's winds, waves, and ice movements. Water depth at the station is more than 18.0 m.

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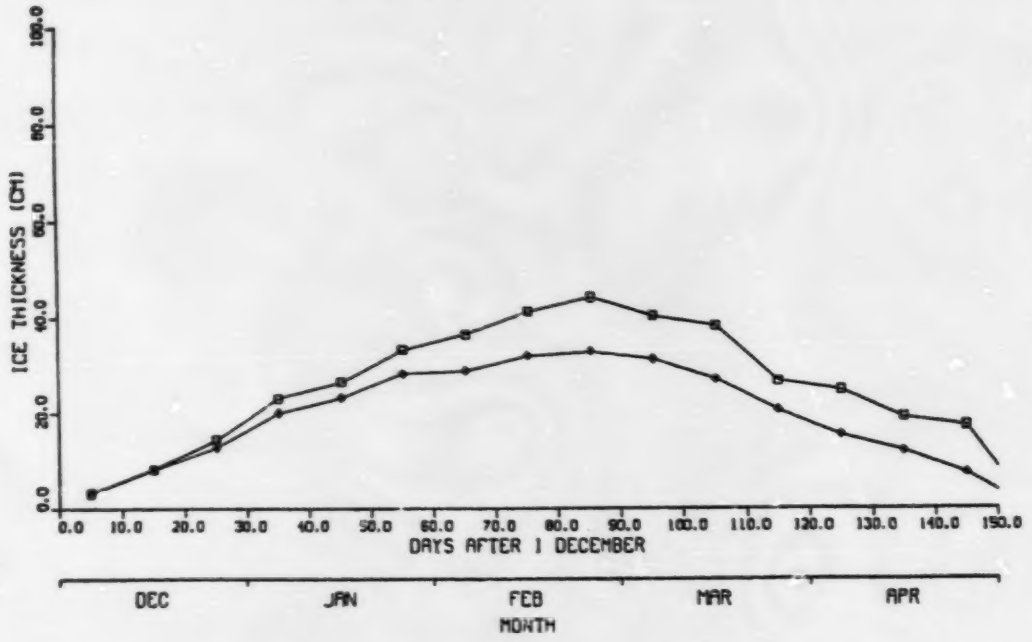

Figure 34.--Average total ice and clear ice thicknesses at North Pond for 1965-79.

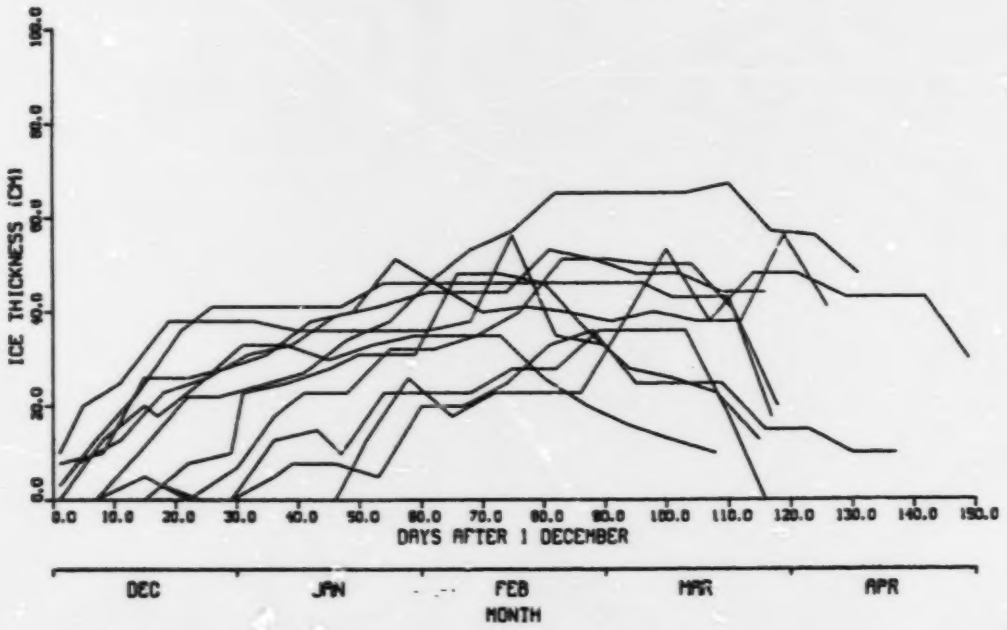

Figure 35.--Total ice thicknesses recorded at North Pond from 1965-1979.

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The average time of freeze-up at this station was the first week in January; times varied from the third week in December through the first week in February. The average time of maximum ice thickness was the third week in February; times varied from the third week in January through the second week in March. Maximum ice thickness averaged 33 cm, varying from 20 cm to 44 cm. The average time of breakup was the last week in March; times varied from the first week in March through the second week in April.

Ice growth rates at this station averaged 7 mm/day; dissipation rates averaged 9 mm/day. The number of days from freeze-up to maximum ice thickness averaged 46 days (a 14-67 day range), and from maximum ice thickness to breakup, 38 days (a 13-49 day range). Ice cover duration averaged 84 days and varied from 51 days to 100 days.

White ice averaged 29 percent of total ice, the highest value of any for the Lake Ontario stations. This is undoubtedly due, at least partially, to the fact that Irondequoit Bay is surrounded by trees and could be considered an inland lake. Snowfall would probably tend to accumulate on the ice. Amounts of white ice as a percentage of total ice varied from 10 percent to 39 percent. Figure 36 shows average total and clear ice thicknesses at this station. The area between the two curves is the average thickness of white ice. Figure 37 shows the total ice thickness for each year, as well as the variation in freeze-up and breakup dates at this station. Note the wide range in breakup dates.

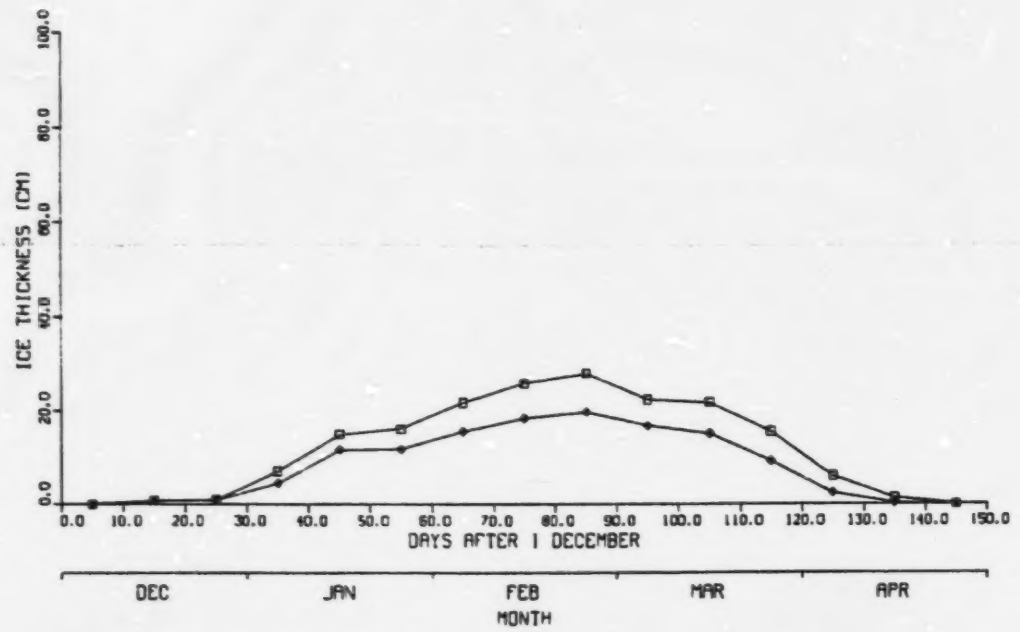

Figure 36.--Average total ice and clear ice thicknesses at Irondequoit Bay-Rochester for 1965-79.

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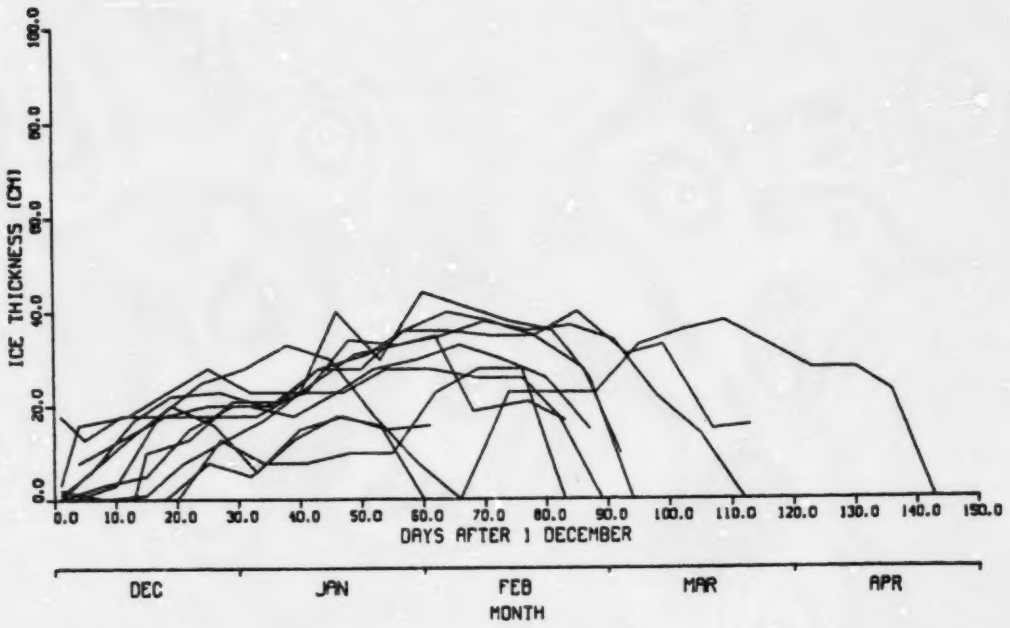

Figure 37.--Total ice thicknesses recorded at Irondequoit Bay-Rochester from 1965-1979.

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